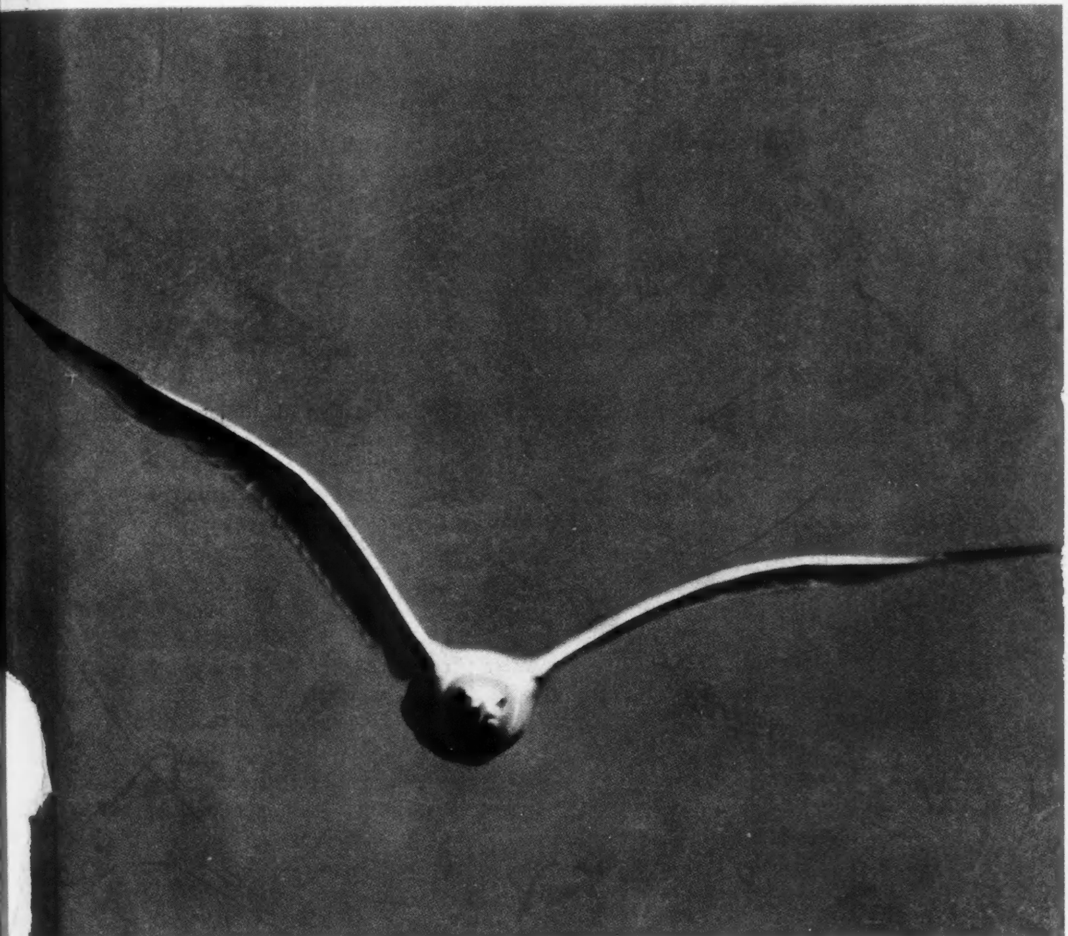
THE POPULAR JOURNAL OF KNOWLEDGE

DISCOVERY

CAMBRIDGE: JUNE, 1938



PROF. J. A. RYLE on: Research on Digestion and Anaemia

DR SVEN HEDIN on: Rediscovering the Silk Road

- The Flight of Birds
- The Grand Canyon
- The Riddle of Sirius
- Radio Exploration of the Upper Atmosphere

1/- NET

DISCOVERY

New Series, Vol. I, No. 3 JUNE 1938 **1*s*. net**

Published by the Cambridge University Press, Bentley House, 200 Euston Road, N.W. 1 (Tel.: Euston 5451–3)

Editor: C. P. Snow, University Press, Cambridge (Tel.: 4226)

Advertisement Offices: 61 Chandos Street, W.C. 2 (Tel.: Temple Bar 6897)

Annual Subscription, 12*s*. 6*d*. net post free

The Progress of *Discovery*

WE have been delighted with the response to the first two numbers of the new *Discovery*. The circulation has multiplied itself more than we hoped; many letters have arrived, and they give us the impression that we are really providing the service at which we aimed.

We are grateful to many friends of the magazine for suggestions and criticisms. Their ideas and interest have helped us in making plans for the next few months. We are now able to announce some of the features which are soon to appear.

In the present issue, Prof. J. A. Ryle describes the advances, during the last forty years, in our knowledge of digestion and of gastric diseases, in particular pernicious anaemia. This is the first of a series upon recent advances in different fields of science, each written by a foremost authority on the subject. Next month, the series will be continued by a description of the last forty years of astronomical research: the author will be Sir Arthur Eddington.

We feel ourselves privileged to be able to publish these articles in *Discovery*. They owe their origin, as mentioned on another page, to the enthusiasm and vision of the Cambridge History of Science Committee. Some months ago, this committee arranged for a weekly lecture on the recent past in science; many of the lectures were given by men like Rutherford who had themselves been the foremost figures in the history which they were relating. It was a romantic and unforgettable experience, to hear of the great discoveries by people who had seen them happen under their hands. Week after week, the lecture-room was packed and electric with attention.

Our present series consists of these lectures, now written for a wider audience. We believe that others will share the original intimacy and excitement.

We are also glad to announce that Dr F. Fraser Darling, the eminent Scottish naturalist, will contribute several articles similar to his "The Flight of Birds" in the present number.

The picture on the cover this month, and the illustrations to his article, are examples of his skill. Readers of *Discovery* will find many more of these beautiful photographs in the next issues.

Ice floes separating before the "Sbiriakov".

The Flight of Birds

By F. Fraser Darling

(Dr F. Fraser Darling is a Scottish naturalist who has won a reputation both for scientific work and for his remarkable skill as photographer and observer of birds and animals. He has written two books full of interest for the layman—"A Herd of Red Deer" and "Bird Flocks and the Breeding Cycle". "Discovery" will publish, in the July and later numbers, more records of Dr Darling's days with notebook and camera.)

SINCE I came to possess a good camera, there is no sport of which I have become more fond than trying to get photographs of birds in flight. It is an extremely difficult sport to follow, but the few successes go far to make up for the long list of failures. The excitement is intense, and when I am working at a cliff edge I take particular care before letting rip that my feet and legs are well placed; so that whatever contortions my head and trunk may achieve, I shall remain on the top of the cliff and not find myself going head first into the sea. Will all young people please make a particular note of this point, and promise not to allow themselves to be carried away by the enthusiasm of the moment?

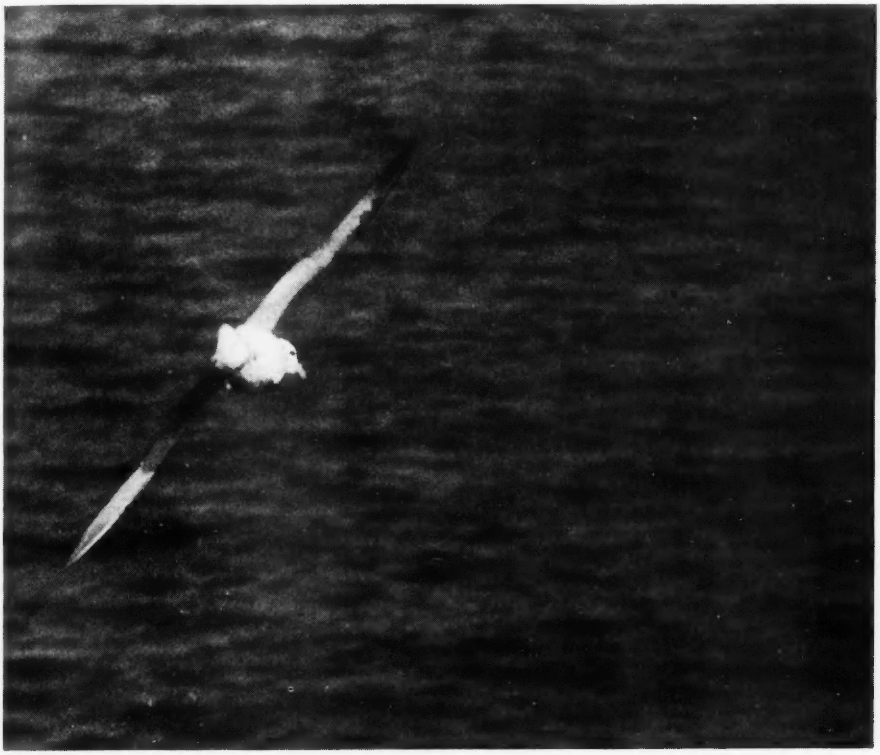
Herring gull making height.

I have mentioned the many failures which are the lot of the photographer of birds in flight; failure should be looked upon as a relative term, if you are really interested in knowing how the bird's wings are disposed in flight. If you get a very fuzzy negative or one in which the whole wing movement is shown, make a print

from it, reconstruct in your mind the positions which the photograph would have shown clearly had it been good, and then take the trouble to draw the bird in those positions. You may not be able to draw, but if you try you will probably find you can, and this exercise of drawing has a remarkable effect in helping you to understand wing shapes and positions in various birds.

I am giving in this article only relatively good photographs of gulls and fulmar petrels in flight, but I have also taken poor ones of shags, oyster-catchers, ravens, sandpipers, geese and solans; I have got hours of pleasure by making drawings from them which have an authentic quality and are not a reconstruction from your memory of what you think a bird is like when flying. How I wish I could photograph the soaring flight of eagle and buzzard on those deep wings of theirs, the clean up and down movements of the rock pigeon, the soft slow flight of the heron, the rapid zigzag of the snipe, the down-curved wings of game birds going down wind, and the flit of fire-crested wrens among the brambles in a winter dusk! Some of these things are possible, some are next to impossible, but all remain to be tried.

I think the photographs given here will show plainly the difference in the types of flight displayed by the fulmar petrel and by herring gulls and greater black-backed gulls. Note first of all the three greater black-backs in flight. These obliging



birds gave me three wing positions in the one photograph, and you will see what a large amount of movement there is at the wrist in their flight. The wrist is flexed more or less all the time when flying, and the upper surface and the front edge of the wing never assume anything near a straight line. In short the wrist always marks an angle. When a bird takes off from the ground the wings are stretched upwards to the utmost and the tips come close together, but in the photograph of the herring gull taking off from the rock the angle at the wrist is still obvious. Again, in a rapid downward swoop the tendency of the air would be to flatten the wings, but those of the herring gull, which is shown hurtling towards the lens of the camera, are still markedly bowed at the wrist.

In the photograph opposite, the end of the fulmar's wing is deflected as she banks against the cliff face.

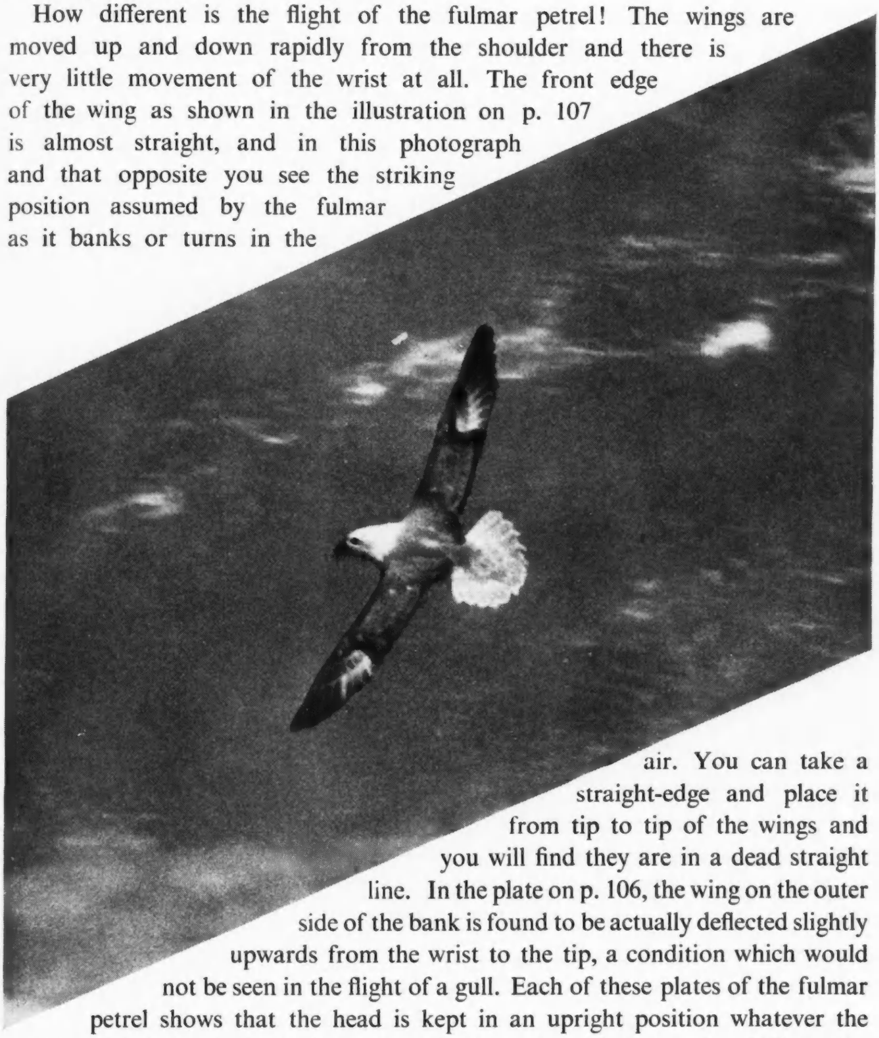
Above: the fulmar moves through the air for long periods with wings in a dead straight line.

The first picture shows a herring gull after having left the ground and in the course of making height. The wings cup the air as much as possible and assume almost a semicircle from tip to tip; the

The fulmar is soaring. The tips of the primaries are opened, and the tail is fanned wide.

tail is also fanned out to offer resistance to the air below, which has been forced down by the sweep of the wings.

How different is the flight of the fulmar petrel! The wings are moved up and down rapidly from the shoulder and there is very little movement of the wrist at all. The front edge of the wing as shown in the illustration on p. 107 is almost straight, and in this photograph and that opposite you see the striking position assumed by the fulmar as it banks or turns in the air. You can take a straight-edge and place it from tip to tip of the wings and you will find they are in a dead straight line. In the plate on p. 106, the wing on the outer side of the bank is found to be actually deflected slightly upwards from the wrist to the tip, a condition which would not be seen in the flight of a gull. Each of these plates of the fulmar petrel shows that the head is kept in an upright position whatever the position of the wings and body. There must be extreme delicacy of mobility in the neck of a bird. The tail positions are also worthy of note; sometimes the tail is used as a rudder, sometimes it is fanned out to the full, and in some flight positions the posterior edge of the tail as seen from behind describes a beautiful arc which may be almost a semicircle.



The tail of the fulmar is sometimes fully fanned.

I include the photograph of the two young greater black-backed gulls, not for any particular posture they illustrate in flight but for the beauty and regularity of pattern which is displayed in this, their first plumage. It is beautiful when seen on the standing bird, but here, where all the feathers of the upper surface are extended and visible, the living pattern is one of remarkable intricacy. I took this photograph one day when I was leaving Iona after having had to make a visit at the wrong time of year. The ship's cook had been heaving garbage from the galley, and the gulls were attracted. Feeling uncomfortable in the press of people, I turned my back on the island and amused myself with the birds, which were so much more tame under these circumstances than they are ever at the breeding quarters.

Young herring gulls in their first plumage.

Three greater black-backed gulls in flight, showing the flexed wings and movement at the wrist. See p. 106.

Notes of the Month

A Virus shown to be a crystalline protein

VIRUSES have sometimes been regarded as the smallest "living things". They are the smallest of the organisms which cause disease: thus measles and smallpox are produced by something too small to be seen under a microscope or to be caught by a filter. Probably influenza is caused by a similar virus. Bacteria, which cause other diseases such as tuberculosis and pneumonia, are considerably larger; and protozoa, which cause dysentery and malaria, are larger still.

For some time the problem of the nature of viruses has captured a good deal of attention. Quite recently it has become one of the most exciting of all biological topics. There is no doubt that these things, when producing disease in another creature, are truly "living". Not long ago, however, one or two typical viruses have been isolated, i.e. pure specimens of them have been obtained by themselves. And these are nothing more or less than crystals of a protein, not very different from many other ordinary organic substances.

These results have been obtained by a series of interconnected researches. Much biological work is now so complicated, and requires so many various kinds of knowledge and technique, that it has to be carried out by teams rather than by single investigators. In this case the work has concentrated upon certain viruses which produce different diseases in the tobacco plant. At our present state of knowledge, plant viruses are more amenable to research than those causing disease in animals.) These viruses were first extracted and isolated by very ingenious biochemical methods (F. C. Bawden and N. W. Pirie). They were then examined crystallographically by J. D. Bernal and his collaborators. There seems no reasonable doubt at all that they are true protein crystals.

This result raises once again the distinctions between "living" and "non-living" things. A protein is, in the ordinary sense, a typical sample of non-living matter. Yet these proteins, as soon as they are at work in the tobacco plant, are genuine living things, as alive as bacteria or protozoa. N. W. Pirie, one of the scientists responsible for this discovery, has suggested that the word "life" is itself a cause of mystification and misunderstanding; we ought to content ourselves, he argues, with more precise definitions.

(*Biochemists: F. C. Bawden, Rothamsted, and N. W. Pirie, Cambridge.*
Crystallographers: J. D. Bernal, London, and I. Fankuchen, Cambridge.)

Nature and the Social Relations of Science

H. G. Wells once said (in *The World of William Clissold*) that *Nature* was the ideal newspaper. Many of us would subscribe to that judgment; its influence on science has been far stronger and far more humane than that of any other journal on the

ordinary course of human affairs. Particularly under the present editor, Sir Richard Gregory, *Nature* has combined fairness and authority to such a point that no English-reading scientist would go for a week without reading the paper through. It is there that he is most likely to find the first announcement of a new discovery (the list of letters to *Nature* containing the first statement of great discoveries is a most remarkable one). It is there, also, that he will find the voice of organized science—the voice of the scientific profession which, for all its faults, has behind it some of the more creditable of human achievements.

Thus the recent lead given by *Nature* upon the relations of scientists to society takes on at once a deep significance.

In a special supplement on 23 April, *Nature* quoted a resolution from the Council of the American Association for the Advancement of Science—"Science and its applications are not only transforming the physical and mental environment of men, but are adding greatly to the complexities of the social, economic and political relations among them", and went on to suggest methods in which scientists might most usefully consider "social problems which science has helped to create and might help to solve".

Nature's actual suggestion is a society for the study of the Social Relations of Science (the S.R.S.) "with a large individual membership, which should not be confined to men of science, though they should play the principal part in it. The Society should have its council, its regular meetings, its publications, and perhaps its committees for the study of selected questions. It should receive, read, discuss, and, after consideration by suitable referees, publish papers submitted to it.... Its field of work would inevitably touch on questions that have a political importance, but its attitude towards papers submitted to it should be scientific and objective...."

Nature then lay this proposal before forty of the most eminent scientists in the country. Almost all of them were enthusiastic, and their criticisms were directed at getting S.R.S. started on a sound foundation. In many of their letters they expressed the fact that our civilization is threatened; a scientific approach to social problems is needed in order to save it.

This supplement to *Nature* ought to be read by anyone concerned with the state of the world to-day.

Identical twins in domestic animals

"Man is the only mammal known to produce not only two egg twins but also one egg twins." This is a statement made by the *Encyclopaedia Britannica* in 1929. It is no longer true to-day. Identical twins (i.e. from the same egg) have been found in some of our domestic animals, though they are rather rare occurrences.

C. Kronacher was, in 1932, the first to undertake a systematic study of cattle twins, and in 1936 he published careful observations of a number of calf couples

which are doubtlessly twins coming from the same egg. Apart from the morphological features usually compared, these couples resembled each other strikingly in their growth curve, the quantity and fat contents of their milk, general temperament and form of heat cycle, ferments and blood groups.

In carnivorous animals and in horses, identical twins do not seem to exist at all. Horse twins, in fact, have not yet been studied. Mostly they are born prematurely and if they are at all able to live, breeders hardly ever bring them both up, because at least one of them is a miserable creature that does not promise a good development.

Systematic twin studies on a large scale are difficult in the case of domestic animals, partly for financial reasons. If, however, they could be carried through, they would afford a better chance to ascertain the influence of changed surroundings than the observations of human beings.

Aerodynamic Skiing

While in the case of automobiles, motor cars and aeroplanes, the modern tendency is to reduce the resistance of the air (stream-line form), the opposite tendency has led Professor Hans Thirring to invent a kind of sail for skiers. He has made the following observation: at the end of long courses, in which the speed is constantly increased, there comes a moment when the skier feels much safer than he felt before. He feels himself resting on the air, as it were, as on an elastic pillow. By giving the skiing dress an appropriate shape, this stabilizing effect of the air current can be increased in such a way that it is not confined to exceptionally high speeds but also produced in normal down-hill running.

The so-called "Thirring cloak", which makes people look a little like bats, is meant neither for beginners nor for racers but for the "skiing middle class". A beginner will not be able to reach a speed high enough to profit by the stabilizing effect of the cloak; and racers, on the other hand, can maintain their equilibrium by skilfully moving their legs and bodies. When armed with the sailing coat, the "petit bourgeois", and the "ski-proletarian", as Thirring puts it, can go down straight, like one of the "upper ten thousand" in the realm of skiing.

An instructive experiment was made with a military skiing formation. A group of untrained but rather reckless skiers equipped with the cloak were accompanied by first-class skiers without the cloak. They went down a very steep slope covered with heavy snow and with big lumps of snow from an avalanche. Very soon the winged skiers had disappeared behind a hill while the second group, ordinarily highly superior to them, was still busy swinging in the big snow. For soldiers—young and daring men who are expected to master any track and any snow conditions after a short training, often even laden with baggage—the sailing cloak is an immense help, as it increases the average speed and stability of the men.

(*The last two notes from Dr. Rabel, Vienna*)

Four scientists make a hazardous journey by boat

Rowing Through The Grand Canyon

By LINTON ECCLES

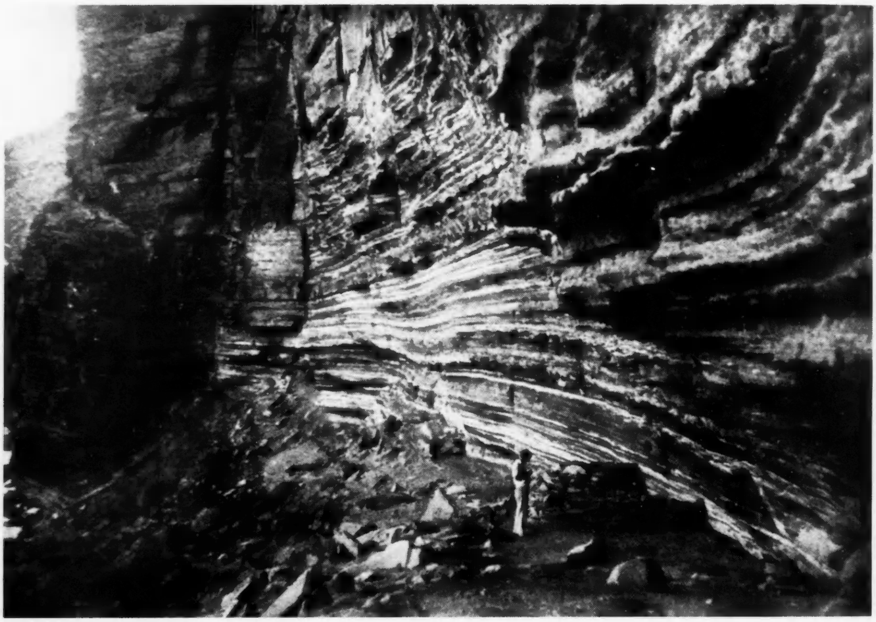
MAINLY in order to study the Archean rocks—popularly known as the "world's oldest"—that lie at the foot of the Grand Canyon of the Colorado River in Arizona, geologists recently made a trip there in rowing boats. They not only rowed through the principal canyon, but made side-trips into a number of the subsidiary canyons never before explored by white men.

The expedition, jointly sponsored by the Carnegie Institution of Washington and the California Institute of Technology and with the co-operation of the National Parks Service, included Profs. Ian Campbell and John H. Maxson of the California Institute; Prof. John T. Stark of Northwestern University, Illinois; Robert Sharp of Harvard University; and three expert river boatmen. Three 16 ft. boats, specially built so as to carry both men and the heavy supplies and equipment and to be at the same time portable and "non-sinkable", were used for the journey.

An interesting special piece of equipment carried was a portable wireless-telephone set, with which touch was maintained fairly regularly with the government ranger and weather stations. Messages requiring prompt attention were relayed from these stations to the California Institute of Technology at Pasadena. A period of about two months, from the middle of October to the eve of Christmas last, was occupied in completing the project so far as field observations were concerned.

For several previous seasons Profs. Campbell and Maxson had carried out

detailed studies of the ancient crystalline rocks in several favourable localities of the Grand Canyon. This latest and more ambitious expedition was undertaken so as to investigate the section as a whole, in the belief that important additions to the petrographic types would be made. Briefly, Profs. Campbell and Maxson report: "This broad and general objective has been fulfilled. Much new information on the geology of the district between Lee's Ferry and Pierce's Ferry, Arizona, has been obtained."



Ruins of an Indian shelter, under a protecting sandstone cliff.

These results are being embodied in reports to be published in technical journals. The present writing is concerned chiefly with general aspects of the expedition. Considerable attention was paid by the geologists, not only to make frequent landings to study and obtain rock specimens, but also to obtain as complete a photographic record as possible. For this purpose two good cameras of regular type were used for black-and-white pictures, and in addition a large number of Kodachrome natural-colour photographs were taken, these recording much of the striking and beautiful colouring of the region.

The judgment of the boatmen, three experienced river men who have spent many years with the National Parks Service, was relied upon implicitly in the management of the three boats. As the dry weight of these alone was 900 lb. and, apart from the human element, much expensive equipment was carried, the question of

whether to "shoot" the many rapids or portage past them was always one requiring nicety of judgment.

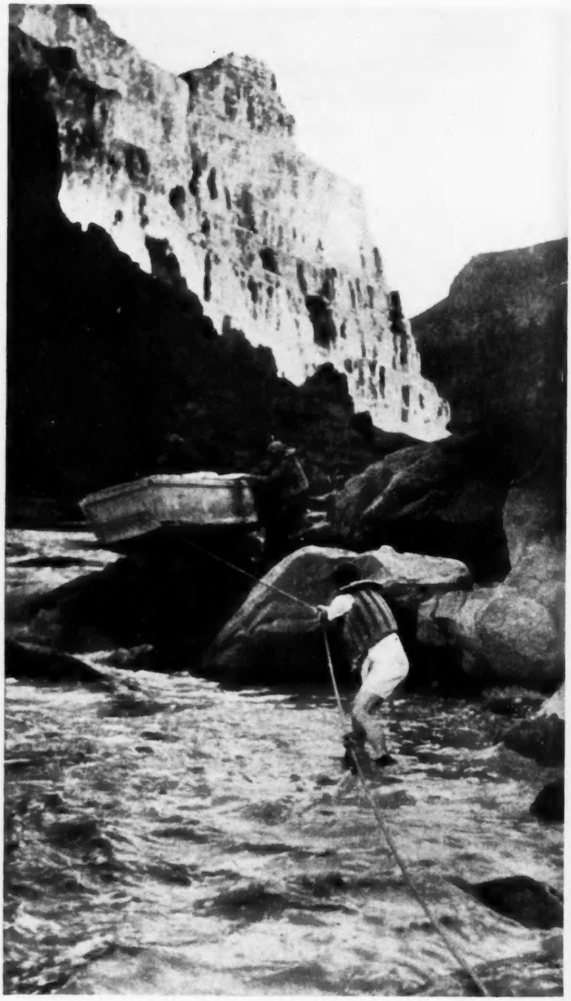
All of the larger navigable rapids were run with the boats stern foremost, so that the boatman could see where he was going and more effectively control his course. Boatmen and geologists wore kapok-lined life jackets. The period from dawn to dusk was occupied in travelling or in rock study, an average of 12 miles a day being maintained. When the Archean rocks were encountered, between Red and Mineral Canyons, progress necessarily was slower. Collections of specimens were made at

The Marble Canyon of the Colorado River, cut through horizontal palaeozoic formations.

close intervals from both sides of the river, and whenever possible for these to be accessible from the rim of the Grand Canyon, caches of the rock specimens were made for recovery at a later date.

Describing the procedure on encountering "rough water", the geologists stated: "When the chief boatman, in the leading boat, felt that too much risk would be involved in running boats through a rapid, it became necessary to 'line'. In the process of lining, a rope is tied to the stern and another to the bow. Where possible, the boat is allowed to descend along small channels near the river bank. The men on the bow line upstream prevent the boat from swinging out into the centre current and prevent it also from colliding sharply with rocks. The chief boatman

and an assistant customarily direct this operation and assist by working alongside the boat. The men on the stern are required for pulling the boat through rocky stretches where there is not sufficient water to float it. Occasionally when exceptionally swift water is very near the shore, it becomes necessary to haul the boat out bodily by means of the block and tackle. Whenever the overland lining of a boat was necessary, its cargo was carried to the lower end of the rapids. Lining was a slow and laborious procedure, but it was considered preferable to taking chances on losing a boat in bad rapids. It was necessary to line Badger Creek Rapids only eight miles below the start at Lee's Ferry, and the time required, one hour for each boat, was the average time required on all subsequent lining jobs."



"Lining."

After passing Soap Creek Rapids no very dangerous swift water was met. Sheer Wall Rapids, at $14\frac{1}{2}$ miles, and considered dangerous, was passed without portaging and without mishap. House Rock Canyon and North Canyon Rapids were "moderately swift, but good channels existed and the boatmen ran the boats through."

After passing Lava Canyon Rapids, 246 miles from the start, the headwaters of Mead Lake—the artificial lake formed by the building of Boulder Dam—were reached. At Pierce's Ferry, 279 miles, the Colorado River journey was successfully completed.

The Granite Gorge of the Grand Canyon from Lone Tree Canyon.

The History of Research on Digestion and Pernicious Anaemia

By John A. Ryle

(*Regius Professor of Physic, University of Cambridge.*)

History, whether political, national or scientific, is largely woven around personalities and movements due to personalities. Scientific history is particularly concerned with movements of ideas, discoveries of fact, and the integration of new knowledge. Political and national histories, on the other hand, are both concerned with and swayed by human passions as well as human thought, and are for these and other reasons more complex and less consecutive.

If we select two of the greatest figures in medical history—Hippocrates and Harvey—we find that, apart altogether from their numerous special contributions to knowledge, both were instrumental in promoting ideas and indicating methods without which biological science, as we know it, could scarcely have been born and certainly could not have prospered. Hippocrates taught the importance of accurate observation of natural phenomena, and was the founder of the naturalistic approach to the study of man in health and disease. Harvey was the founder of the experimental method, a physician by training, but the first great systematic physiologist.

Advancement in medical learning has depended upon the simultaneous but not always parallel development of the observational and experimental schools. Rapid and steady improvements in technique, refinements in the actual tools of experiment, the interactions of the more precise sciences, and the inevitable and necessary specialistic trend have between them provided a continuous impulse for the newer method, but in the process have brought about a certain cleavage between the two schools which can be of advantage to neither.

"Gastric History"

A study even of so small a fragment of medical and physiological progress as may be comprehended within the two words "gastric history", reveals at once the close and intimate interdependence of the observational and experimental schools, reminds us of elementary but important steps and stages which, in the abundance of our modern equipment, we are apt to forget, and adds character and even romance to a chapter of knowledge which the necessary discipline of science might otherwise render needlessly austere or present-day familiarity too commonplace.

Of the more famous students of gastric physiology two stand pre-eminent, and I shall naturally concern myself much with them and their work. I refer to William Beaumont (1785–1853) the American army surgeon, and Ivan Pavlov (1849–1936) the great Russian physiologist, whose death we mourned a short time ago. Gastric physiology may almost be said to have been born with Beaumont's observations. Before his day the functions of the stomach were very imperfectly understood. William Hunter (1718–83), discussing current opinions, summarized the situation in his day as follows: "Some physiologists will have it that the stomach is a mill, others that it is a fermenting vat, others again that it is a stewpan; but, in my view of the matter, it is neither a mill, a fermenting vat nor a stewpan but a stomach, gentlemen, a stomach."

De Réaumur (1683–1757), who invented a thermometer and introduced the scale of temperatures which still bears his name, had a pet buzzard and obtained from it samples

of gastric juice by persuading it to swallow small perforated tubes containing fragments of sponge. He described the taste and acid reaction of the juice and suggested experiments to test its digestive power. We should remember also that Spallanzini (1729–99) performed experiments on himself, swallowing small linen bags containing food and recovering them on evacuation and estimating the weight-loss of their contents through digestion; he also conducted experiments on animals, and established that gastric juice prevented putrefaction. Prout (1785–1850), the first English physiological chemist, showed that the acid of gastric juice was hydrochloric acid—a very important discovery. But it remained for Beaumont to prove in man and to correlate anew these piecemeal observations, adding at the same time much new knowledge and presenting a detailed and comprehensive picture of the whole cycle of gastric digestion.

> ***Two years ago, largely through the efforts of Dr Joseph Needham, a series of lectures on the history of science was arranged in Cambridge. Nothing of the kind had been given before, and the lectures drew large audiences from the beginning. They filled a real need, and proved that the history of science is a living subject. The whole course will eventually be published as a book. It consisted of ten lectures on the modern period*** **1895–1935,** ***by scientific investigators who had themselves made fundamental contributions to science during that time. Meanwhile we are glad to be able to publish some of the series in Discovery. This month we give Professor J. A. Ryles's lecture, to be followed in July by Sir Arthur Eddington's, and in August by Lord Rutherford's (his last public lecture).***

A Curious Occupation

This he did by seizing the opportunity provided by a serious accident with a shotgun, which occurred on 6 January 1822 at Fort Mackenzie, a frontier outpost and trading station at the junction of Lakes Michigan and Huron. The victim of this accident, Alexis St Martin, a French Canadian, received the charge at a distance of 3 ft. under the left breast, a large part of his side was blown away and several ribs were fractured. Portions of the lung and stomach protruded in the wound; the diaphragm was torn and the stomach opened. Beaumont attended to him with infinite care for many months. He was left with a gastric fistula, but otherwise well; he was, however, destitute, without occupation or pension, and at first from physicianly compassion and to save him from being sent away to his birthplace in Canada, since the local authorities would not care for him, Beaumont adopted him and kept him in his own house. Six months after the accident a portion of the gastric mucous membrane prolapsed and, by another happy chance, formed an excellent valve which prevented the spontaneous escape of gastric contents. Ultimately in 1825 Beaumont drew up an agreement with Alexis to keep him in his employ for the purpose of his physiological experiments. These experiments continued for eight years with few interruptions, Alexis receiving his board and 150 dollars a year. When the agreement terminated, Beaumont made repeated attempts to get Alexis to come back to him for further experiments but without success.

Without a close perusal of Beaumont's work, which he entitled *Experiments and Observations on the Gastric Juice and the Physiology of Digestion*, it is impossible to obtain a true conception of his patience, his thoroughness, his resource and of the eager, accurate, scientific spirit by which all his investigations were actuated. The various sections of his little book deal with Aliment; Hunger and Thirst; Satisfaction and Satiety; Mastication, Salivation and Deglutition; Digestion by the Gastric Juice (in the

stomach and *in vitro*); the Appearance of the Villous Coat (in healthy states and during indisposition or fever and after drinking bouts); Chylification and the Uses of the Bile and Pancreatic Juice. The motor, secretory and sensory functions of the stomach all received close attention. Hundreds of foodstuffs were tested with regard to their rapidity of digestion in the stomach, and also with juice removed from the stomach and placed in a vessel over a water-bath. The temperature of the stomach before and after exercise was recorded, and with the long thermometer which he used he was able to note how the pyloric portion of the stomach grasped and drew the instrument towards the pylorus, and later thrust it back again, and how, also, a distinct rotary movement was simultaneously imparted to it. He described and discussed the action of the longitudinal and transverse muscular fibres. He established that hydrochloric acid was an active principle of human gastric juice, as it had been shown to be of the juice of other animals. He also forecast the presence of some other agent to which Schwann in 1835 gave the name of pepsin. The antiseptic (or anti-putrefaction), as well as the digestive effects of gastric juice were also demonstrated.

Beaumont: Gifts and Luck

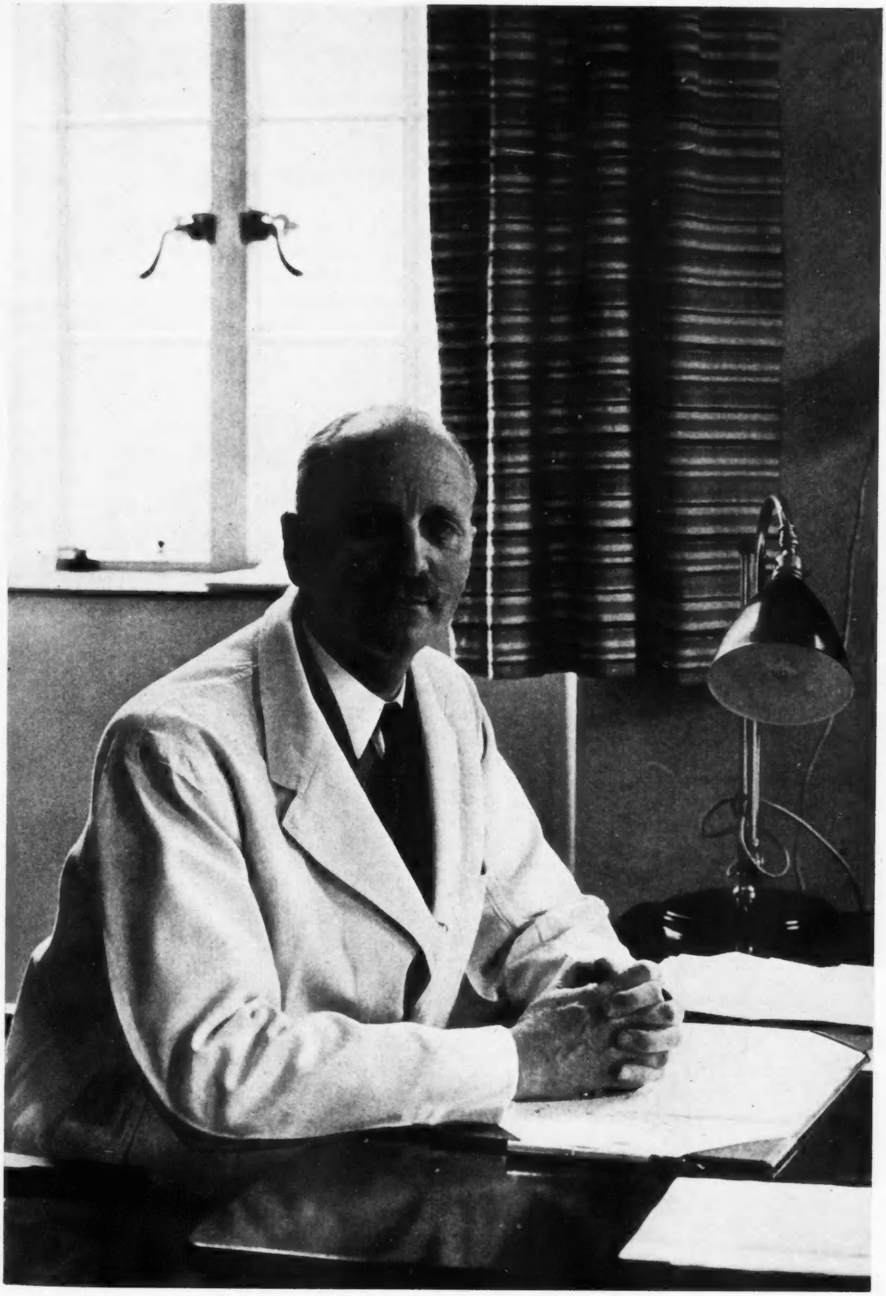
For what must we particularly commend Beaumont beyond his experimental zeal and his patient quest for new truths? We cannot but be impressed by the promptness and sureness with which he grasped the opportunity presented to him by a rare accident. How many men would have had the requisite vision and ingenuity and persistence in the same circumstances? What a fortunate chance it was that the right man and the right opportunity were contemporary; what a fortunate chance that with Beaumont's practical skill to help him, Alexis should recover from so grave a wound and not die from shock, haemorrhage and peritonitis, or any of the possible sequels of such an injury, and still more that he should survive to enjoy full health. Without this full health the experiments could not have been regarded as "physiological".

It was genuinely a rare accident. During the whole period of the War and among a very large number of abdominal and thoracic wounds I cannot remember seeing any comparable case. Modern missiles, no doubt, have rendered appropriate wounds more certainly lethal; the long intervals which necessarily elapsed between the wound and the arrival of the soldier at a clearing-station added to their fatality; modern surgical technique no doubt repaired injuries which might have resulted in fistulae. Even so such a valvular fistula as Alexis developed clearly requires a very special sequence of chances. Without these chances and this man our knowledge of gastric physiology might have been seriously retarded and lacked completion even to this day. In Beaumont's action we have already a lesson from history, for it is certain that other accidents and diseases are still waiting to be seized upon and studied for the benefit of physiology as well as practical medicine. We are entitled to ask ourselves whether Pavlov (who naturally makes reference to Beaumont's observations), improving upon the methods of Heidenhain, would have evolved his wonderful animal experiments without the inspiration which the young army surgeon had provided.

For a truly delightful account of Beaumont and his work I would refer you to Osler's "A Backwood Physiologist", included in the *Alabama Student*—the best, perhaps, of the many fine biographical essays included in that book.

Another Type of Genius

In Pavlov we encounter another type of genius. Without the accident it is more than likely that Beaumont would have made no lasting contribution to science. Pavlov, as determined a searcher for the truth as Beaumont became, would, one is tempted to infer, have become what he became, a



PROFESSOR J. A. RYLE

great experimenter, in almost any circumstance. He added to the qualities which Beaumont developed experimental ingenuity and operative skill—he was ambidextrous—and an ability in the planning of experiments which have remained unsurpassed.

Those who are familiar with his later as well as his earlier work will appreciate what a master mind he possessed. He knew from the earliest days that his surgery must be precise and aseptic, that his operations for the production of a gastric pouch (the functions of which could be studied even more minutely than the stomach of Alexis and which allowed him to obtain pure juice unmixed with food), must be technically perfect, that he must leave circulation and nerve supply intact, and maintain his animals in a state of unimpaired general health. Indeed the health and happiness of his dogs was always a matter for very particular concern. Their psychology too must needs be attentively watched and understood. His beautifully controlled work on conditioned reflexes has opened a new chapter in the objective study of psychological processes. It grew in direct sequence from the work on the digestive glands.

Pavlov and his Dogs

Pavlov's name has been particularly connected with studies of secretion directly induced by food and of so-called psychic secretion. The Russian edition of *The Work of the Digestive Glands* was published in 1897. Like Beaumont he noticed the effects and studied the digestion of a great variety of foodstuffs, but with a much greater precision and with minute measurements of the amount and rate of secretion and the rate of digestion. Like Beaumont, however, he did not confine himself to physiology, but made experiments in connexion with gastric pathology and therapeutics which have had their influence on practical medicine. He was his dogs' physician as well as their surgeon and a master of technique. His breadth of view compelled this. The continuity between physiology, pathology and therapeutics appealed to him more than it has done to the majority of physiologists since his day, and is repeatedly emphasized in his writings. He inspired a large band of loyal disciples, as is evident from the extensive bibliography of the various subjects which he and they have illuminated.

In common with many of his countrymen Pavlov suffered greatly at first from the revolution, but in his latter years the Soviet authorities were fully alive to the great fame which he had brought to Russia and gave him the support and privileges which he deserved. I met him once only and had the honour of helping him into his coat; his fine rugged old features will not readily be effaced from my memory.

Three Types of Stomach

What contributions since Pavlov's gastric experiments have helped to advance our understanding of gastric physiology and pathology? The advent of radiology and its application by Cannon in 1897 to animal experiments by the study of gastric movements and form with the opaque meal, and the later application of the method of human physiological studies by Hurst and many others, have provided important new chapters. The shape, the tone, the position, the peristaltic behaviour and emptying rate of the stomach have been closely studied. The variability of the organ in men and women of varying physique has been established by numerous observations both in healthy and sick folk. The old fixed ideas of the anatomy books have had to be abandoned. Three main types of stomach, the so-called hypertonic (or short) stomach, the orthotonic, and the hypotonic (or long) organ are recognized. Cannon observed the effects of emotion on the stomach of the cat, and Barclay, who worked at Cambridge, has made some observations on emotional reactions in man. Cannon, a physiologist, must be acclaimed as the discoverer of a method which has done more, perhaps, for clinical gastro-enterology than Laennec's

discovery of the stethoscope did for the study of heart and lung disease. With the *opaque* meal, accurate diagnosis of gastric and duodenal ulcers, and pouches, pyloric spasm and stenosis, and of new growths are now possible in a very high percentage of cases. The clinical radiology of the alimentary tract has acquired a vast literature.

The study of form and movement was preceded by studies of secretion. John Hunter, before the days of rubber tubing, had suggested the use of an eel's skin introduced with a probang as a tube for gastric lavage. Although gastric lavage with tubes had been employed before, Leube in 1871 was the first to use the stomach-tube as a means of obtaining gastric contents for analysis. Until 1914, when Rehfuss introduced the more valuable and informative method of fractional gastric analysis, Ewald's one-hour test-meal, with estimation of gastric acidity following a meal of tea and toast, was generally employed in clinical work.

Varieties among Normal Men

Shortly after the War the Guy's school, repeating and extending the work of Rehfuss and his collaborators in America, conducted extensive observations with the fractional test-meal in a large series of healthy medical students with a view to establishing the limits of gastric acidity and emptying time, and the variability of the response to a standard meal of gruel. Just as the stomach was shown to vary in shape and position in health, so too a wide variability in secretory activity was demonstrated, and among healthy men examples of extreme "hyperchlorhydria" and "achlorhydria" were found.

The limits of physiological variability are always worthy of study. It is possible, but not proven, that these variations may throw some light on the question of innate predisposition to certain types of disease. The high hypertonic stomach with a high acidity is a very frequent association with duodenal ulcer; achlorhydria is an almost constant precursor of pernicious anaemia. Injections of histamine which stimulates the secretion of gastric juice are now frequently used in conjunction with the gastric tube. They help to distinguish a false from a true achlorhydria.

In the last twenty years the output of literature on gastric secretion has been enormous in all countries of the world. Pavlov's conclusions have found no refutation, but much has been learned about the behaviour of the human stomach in health and disease. The extension of Pavlov's correlative studies on salivary secretion, already referred to, in order to demonstrate the conditioned reflex, has instructed us in regard to another continuity, familiar to physicians in a general way—namely that which exists between psychological and physical function, between the activities of the special senses and the cerebral cortex and those of the viscera and the secretory glands. The interrelated disturbances of mind and stomach provide constant problems in practice, and await a more scientific elucidation.

The Latest Method of Clinical Study

The newest method of clinical study is gastroscopy. A flexible gastroscope has made it possible to examine visually wide areas of the stomach wall, thereby enhancing our appreciation of the minor changes affecting the gastric mucosa and our general knowledge of living pathology, and adding a diagnostic weapon for use in special cases where clinical analysis, radiology and the test-meal do not give us the information we require. Certain appearances with which the gastroscopist is now becoming familiar were clearly described by Beaumont a hundred years ago. Our knowledge of what Lord Moynihan called "the pathology of the living" has also been appreciably advanced by the gastric surgeons.

Thus far I have confined myself to a consideration of the objective, but the stomach is a sensitive organ, and much

valuable work has been done upon its subjective sensations both in health and disease. Experiments on sensation must, almost of necessity, be conducted on the human subject, and so it is not surprising to find that the physician-physiologist has made a larger contribution than the laboratory physiologist to this branch of knowledge. Hurst, in his Goulstonian Lectures on the "Sensibility of the Alimentary Canal" (1911), showed that the gastric mucosa is insensitive to tactile and thermal stimuli, and that sensations of fulness and pain are due to tension in the plain muscle fibre. The pain of ulcer, formerly thought to be due to chemical irritation of the ulcer base by acid, is now regarded as due to a secondary spasm or increased tension in the muscle fibre. Carlson in an important series of investigations on "The Control of Hunger in Health and Disease" (1916) demonstrated the association of the local hunger-sensation with increased peristaltic activity.

Pernicious Anaemia

I must now ask you to take a jump which may at first seem quite unwarrantable. Where, you may well ask, is the continuity when I remind you that in 1849 and 1855 Thomas Addison, a Guy's physician, and the discoverer of the disease of the suprarenal capsules which bears his name, described also a second disease now generally referred to as pernicious, or Addisonian anaemia? It was, in fact, while investigating this anaemia that he happened upon the disease of the suprarenal capsules. In the preface to his monograph on disease of the suprarenal capsules he particularly remarks upon the contributions which pathology may make to physiology, but he could scarcely have foreseen the outcome of his two discoveries.

Pernicious anaemia, a disease characterized by a profound pallor and weakness, sore tongue, splenic enlargement, a tendency in some cases to a mild chronic diarrhoea (which is relieved by the administration of small doses of hydrochloric acid), and in a smaller proportion of cases to degenerative changes in the posterior and lateral columns of the spinal cord, was formerly almost invariably fatal within a few months or years. To-day it can be readily cured. In approximately 100 per cent of cases the test-meal reveals a complete absence of hydrochloric acid. Since the War, largely as the result of investigations by Hurst and his co-workers, the essential unity of pernicious anaemia and a nervous disease known as subacute combined degeneration of the cord (which sometimes develops without conspicuous anaemia) has been demonstrated. In the vast majority of cases in both conditions achlorhydria is present, and histamine provokes no acid secretion.

A Cure Discovered

Prior to ten years ago attempts were made by a variety of means, including the administration of large doses of hydrochloric acid, eradication of oral sepsis and blood transfusion to cure the disease, but without success. Iron is of no account. Addison's anaemia remained a baffling problem. Occasional cases, however, in which the gastric secretion returned, have recovered completely. In 1926 as the result of some work by Whipple on experimental anaemia in dogs and the diets which most quickly promoted a regeneration of haemoglobin, it occurred to Minot of Harvard to treat a series of cases of pernicious anaemia with liver. It was soon discovered that, given large quantities of fresh liver, patients with pernicious anaemia could be restored to health and kept well so long as the liver treatment was continued. Later liver extracts were prepared which were equally effective, and in quite recent times still more potent extracts which can be given by subcutaneous injection, with very rapid regenerative effects on the blood, have been added to us. Extracts from pig's stomach given by Minot were shown to have a similar potency.

Here then was a substance apparently essential for the maintenance of a normal blood and the absence of which occasioned a disease in persons whose stomachs were unhealthy to the extent that they did not secrete hydrochloric acid. It was at the same time apparent that not all people required liver to keep them well, that vegetarians usually escaped anaemia, and also that deficiency or absence of hydrochloric acid was not itself the cause of the anaemia, since achlorhydria is a not infrequent finding in routine test-meal work and in the absence of any tendency to anaemia.

It next occured to Castle (1928) to see whether anything could be extracted from meat by normal gastric digestion, which could not be extracted with the known constituents of gastric juice such as hydrochloric acid and pepsin and remain *in vitro*, and which might provide the anti-anaemic factor shown to be present in liver and some other organ extracts, particularly stomach extracts. By digesting beef-steak in the stomach of a healthy individual he recovered from the digested products obtained through a stomach-tube a substance which, when fed to a pernicious anaemia patient, caused a reticulocyte response and corrected the anaemia exactly in the same way as liver extracts. This substance is absent from the gastric secretion of patients with pernicious anaemia, but Witts and Hartfall (1933) showed that the gastric juice of patients with a microcytic achlorhydria or iron-deficiency anaemia contained the same property as normal gastric juice.

It now therefore appears that there are two factors, one present in liver and one provided by the stomach which can extract from other foods a factor like the first and as capable of preventing the development of pernicious anaemia and of curing it. These substances are spoken of respectively as the "extrinsic factor" and Castle's "intrinsic factor".

Pernicious anaemia also occurs in a small proportion of cases of gastric cancer and in some cases in which large parts of the stomach have been surgically removed for simple or malignant ulceration. In both we must presume that it is the factory for the intrinsic factor which has been removed whether by disease or the knife. In both cases liver can benefit the condition.

Meulengracht (1935), by means of some very careful anatomical, histological and clinical investigations has now shown that in the pig's stomach the pyloric glands and (in the duodenum) Brunner's glands and to a much less extent the cardiac glands contain the anti-anaemic factor, and when given in dried form to patients with pernicious anaemia produce a good reticulocyte response and correct the anaemia. The fundus or peptic glands on the other hand produce no such effect.

To some extent, therefore, it has been shown that the "lesion" of pernicious anaemia can be localized not only to the stomach but to certain areas of the stomach. This investigation also helps to explain the fact that the operation of gastrectomy does not always cause pernicious anaemia, Brunner's glands in the duodenum and the cardiac glands being able to supply the deficiency even when a large part of the stomach, including the whole of the pyloric area, has been removed.

Meulengracht's discovery may, perhaps, make it possible to produce pernicious anaemia in animals for the first time, and thereby facilitate future experiment and the testing of therapeutic substances.

In a small proportion of cases both pernicious anaemia and gastric carcinoma are complicated by a peripheral neuritis with weakness and disordered sensation in the limbs. Evidence is accumulating that this can be cured by vitamin B injections. Chronic alcoholism may also be complicated by peripheral neuritis. It was formerly supposed that this was due to some direct intoxication by alcohol. It has recently, however, been shown by Strauss (1934) that it can be cured by liver extract and vitamin B injections even when the alcoholism is allowed to persist; it is therefore a sequel, in all probability, of damage to the gastric mucosa and so allied to the

peripheral neuritis of pernicious anaemia and gastric cancer. Liver itself is rich in vitamin B. May it be that to peripheral neuritis in these three conditions (pernicious anaemia, gastric cancer and alcoholic gastritis) is the same as the peripheral neuritis of beri-beri but due, partly, perhaps, to an insufficient intake of vitamin owing to perturbed digestion and appetite, but partly also to a failure to utilize what is ingested on account of the disease of the gastric mucosa and its secreting cells? At least we have a hint here of yet another continuity, linking gastric physiology without knowledge of the protective action of vitamins, and promoting the conception of a "conditioned deficiency disease".

Psychology and general medicine as well as physiology owe a debt to Pavlov's work on the digestive glands. Physiology, as well as neurology and general medicine, owe a debt to the recent work of Minot and Murphy, Castle, Meulengracht and Strauss. We have reached a point at which we may claim that the stomach, in addition to its well-established digestive and general nutritional functions and the antiseptic action of its juices, has another very essential and special nutritional function on behalf of the most important of all the tissues of the body —namely the blood and the nerve cells.

It is highly doubtful whether the experimental physiologist could have discovered this for himself or even guessed at the necessity for the discovery. He has not given an animal pernicious anaemia; human cases do not come his way. The links in the chain have been provided by Addison who described pernicious anaemia; by other physicians, including Fenwick, Faber and Hurst, who have insisted on the probable importance of this constant gastric pathology proclaimed by achlorhydria and on the unity of pernicious anaemia and subacute combined degeneration of the cord; by Whipple who treated artificial anaemia in dogs with diets rich in liver and kidney; by Minot and Murphy who treated pernicious anaemia in man with liver; by Castle who devised the human experiment to prove the existence of an intrinsic factor which is not hydrochloric acid or pepsin or rennin; by Meulengracht and his collaborators who have localized the lesion of pernicious anaemia; by the surgeons who have unwittingly caused pernicious anaemia by the operation of gastrectomy; by the physicians who have studied the similar peripheral neuritis of pernicious anaemia, gastric cancer and alcoholism; and by the pathologists and the gastroscopists who have described the morbid changes in the gastric musoca. In the process a great stimulus has been given to the study of other blood diseases; it has already been shown by Witts and others that another serious form of anaemia differing in certain essentials from pernicious anaemia, although likewise associated with achlorhydria (but not with an absence of Castle's factor), can be cured by massive doses of iron.

Physiology, pathology and therapeutics have joined hands. The clinicians have taught the physiologists things of great importance which they did not know in return for things of great importance which Beaumont, Pavlov, Cannon and others have contributed to medicine.

"An Accident and a Disease"

The earliest discovery of importance was that the stomach secreted hydrochloric acid. The latest discovery of importance is that an absence of hydrochloric acid is sometimes associated with an absence or deficiency of a substance of far greater import to life and health than the acid and other simple constituents of gastric juice. An accident and a disease have between them contributed more to our knowledge of gastric physiology than all the staged experiments put together. On the other hand physiological experiment with the opaque meal has provided clinical gastro-enterology with its most useful diagnostic method.

Some of us work primarily for the amplification and refinement of natural knowledge by experiment, others primarily for the study of nature's experiments, of disease

at first hand, and for the comfort of sick men, women and children, but consciously or unconsciously we are constantly making contributions to the solution of one another's problems. Historical review is valuable if only to remind us of the manner and fruits of this co-operation, and of the necessity for making it more intimate. Observation and experiment have both played their part in the developments which I have all too briefly sketched. It would be invidious to attempt to apportion credit and, indeed there seems to me to be no reason for trying to do so. We may, however, consider the manner of the respective contributions. Speaking generally we may say that experiment by its measurements and accuracies, by its set conditions and repetitions and comparisons, establishes truth more firmly, proves or disproves hypotheses more certainly, and by its originality claims our constant regard for man's ingenious mind. Observation, on the other hand, by telling us, as accurately as may be and repeatedly recording what nature is doing, often gives the impetus and direction for experiment and prompts ideas which could not otherwise have been born. By taking the broad view, and by hypotheses and correlations made possible thereby, it counterbalances the more microscopic studies of experiment. From time to time, by utilizing one of nature's accidents (or experiments), as Beaumont and Minot did, it provides the impetus for epoch-making advances in knowledge.

Poplar trees on the Silk Road (*see Dr Sven Hedin's article on the next page*).

Rediscovering the Silk Road

By SVEN HEDIN

(There is no greater authority on Central Asia than Dr Sven Hedin, the famous Swedish explorer.)

EVERYONE who has studied Latin knows that the ancient Romans were acquainted with silk.

Pliny wrote of it, and the poets Ovid, Virgil, and Horace lauded this fine, thin material. Caesar entertained his people with plays staged under tremendous silk awnings. The Parthians flying banners of silk defeated Crassus at Carrhae. And Seneca warned his countrymen not to let their wives and daughters wear dresses of this transparent cloth, through which the lines of the body were revealed, causing a demoralizing effect on discipline and home life.

But whence came this cloth with the metallic lustre that so fascinated Roman patricians? They did not know. Merchants to whom they paid their gold said it came from the land of the "silk-producing *Seres*", far to the east. But just where the Seres dwelt was a mystery, for the Romans had no knowledge of China. And the Chinese, on the other side, started their silk caravans westward to countries equally unknown to them.

Even long before Rome's imperialistic period, silk was being exported to the Occident. In Kerch in the Crimea, on the Black Sea, silk has been discovered among the relics of the ancient Greek colonies, and Nearchus, Alexander the

Great's strategist and admiral, speaks of the "Seres' materials" India received from the northward.

We like to think of Marco Polo as the greatest and best known of Asian explorers. By his daring journey in 1273, he opened to the Western Hemisphere the door of knowledge to the limitless spaces in the interior of the world's largest continent. But he was not the first European to dare to travel thither. More than 1000 years before, in the 1st century A.D., the Macedonian silk merchant Maës Titianus had agents in what is now East Turkestan. Their descriptions of the previously unknown countries found their way to the hands of the geographer Marinus of Tyre, who in turn became an invaluable source of information to the Alexandrian geographer Ptolemy. In the latter's descriptions of the interior of Asia, *Scythia extra Imaum* corresponds to East Turkestan, the westernmost part of China's possessions, inhabited by Turkish people.

But even centuries before the commercial travels of the silk-buying Macedonians, the Chinese had gained knowledge of the inaccessible parts of the Old World, which at a later period was intersected by the Silk Road. In 138 B.C., the great

Skeleton of camel marking caravan route through the Gobi Desert.

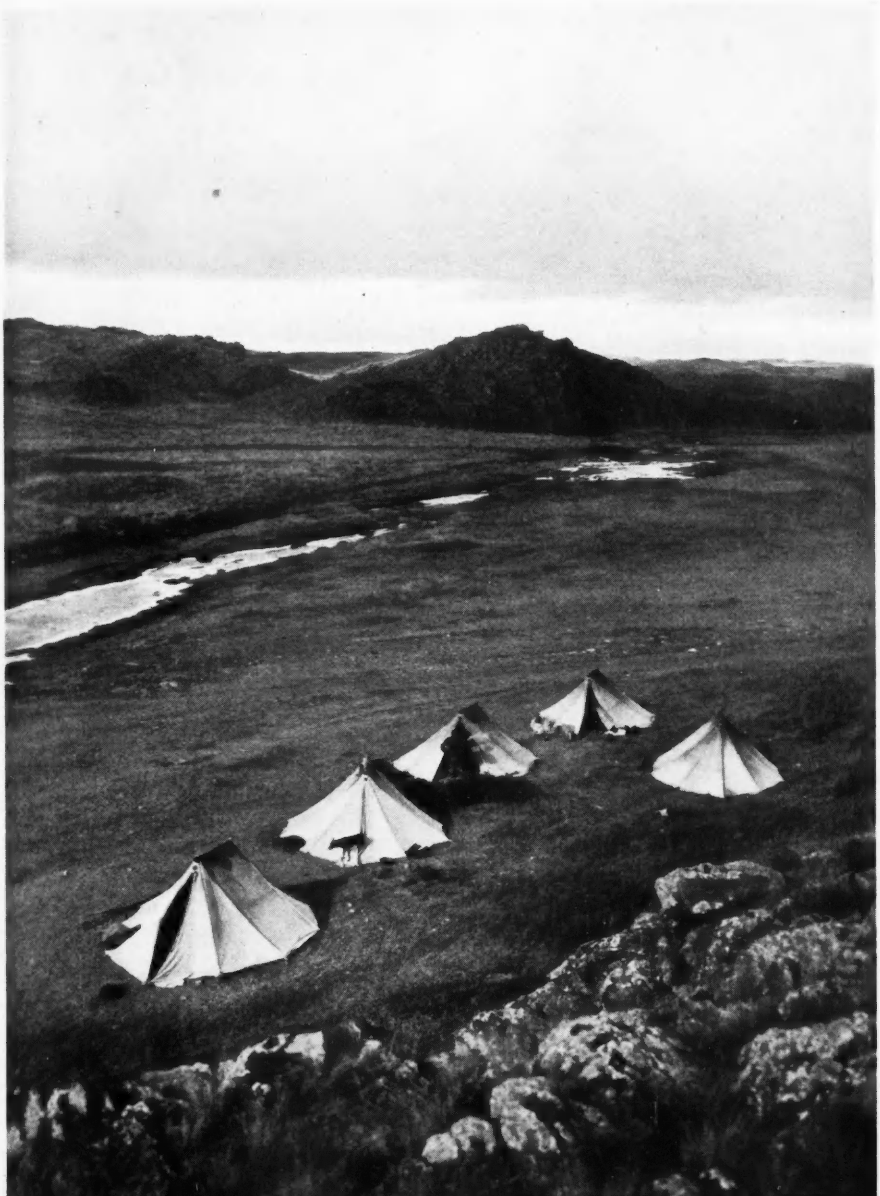
emperor Wu Ti, of the older Han dynasty, sent Chang Ch'ien in charge of a diplomatic and political embassy to Yueh Chih, a tribe which had settled in Ferghana, having been driven away by the Huns, the brave race of cavalrymen inhabiting the steppes and deserts of Gobi.

Though Ch'ien's mission was to incite Yueh Chih to a war in alliance with China against the Huns, he failed completely in his mission. But upon his return he brought to Emperor Wu Ti exciting news of how he had travelled through a series of prosperous oases and countries down to Kashgar, about great commercial roads issuing forth from these regions leading to India and Persia, and of powerful people living in countries stretching down to the Caspian Sea. Chang Ch'ien had found a high degree of civilization and tremendous wealth, and the intelligent emperor listened with satisfaction. He understood what commercial relations with these people would mean to China.

After two successful military campaigns against Yueh Chih, the Chinese came in direct contact with the Western people and their commerce. New roads were constructed to aid in the exchange of merchandise, and arts and crafts also travelled on these roads from West to East, and vice versa. Also they became the means by which missionaries spread Buddhism as far as to the "Middle Kingdom".

Most important for the Chinese of all these roads was "The Imperial Road", which stretched from Sian Fu north and westward over Lanchow, Liangchow, Kanchow, Suchow, and Ansi to Tunhwang and farther over Lou-lan at Lop-nor to Korla, Kutcha, and Kashgar.

The building of the Great Wall had been begun by Emperor Shih Huang Ti in the 3rd century B.C. This Wall was now extended and lengthened by Wu Ti. The most gigantic of all human undertakings on earth, this was intended to serve, not only as a protection for China against the barbarians in the North and North-west, but as a defence for the most important artery of the new commerce.



Camp near Lake Lop-nor.

Of China's many commodities the most important was silk. Western countries seem to have had an insatiable desire for it. For centuries, just before and after the Christian Era, caravans left for the West so frequently that the rider of the last camel in one caravan could sight the first camel of the following. And all these thousands of camels were laden with bales of silk. Ox-driven carts, too, were used for transport.

Though Chinese authorities otherwise have little or nothing to report of the picturesque and colourful life along this almost endless road, one can be sure commerce was intelligently and efficiently organized. Hostelries and inns; military posts and forts to defend the transports; mounted police and customs stations for control; couriers carrying mail in sealed leather saddle-bags; and couriers bringing orders to the military posts—these were all part of a vast organization along this commercial route. At all boundaries interpreters were available, and water was transported on camels to the arid posts in the desert between Tunhwang and Lop-nor.

Those who nowadays travel the old roads in Asia's interior and who are familiar with the Chinese way of travel can without difficulty picture scenes from this kaleidoscopic carnival. They can visualize the important ambassadors with their vast and resplendent entourages and escorts, the rich merchants with their expensive wares, the high officers heading military divisions armed with halberds, lances, swords, bows and arrows, and hear the constant ringing of the bell collars on the horses, the bellowing of camels, the shouting of drivers, the neighing of horses, the

Mongolians at Edsin-gol.

loud music of drums and pipes, the jesters' and jugglers' bawdy songs, the psalms of the pilgrims, the hawking of sweets and other refreshments by wandering tradesmen, the entreaties of beggars.

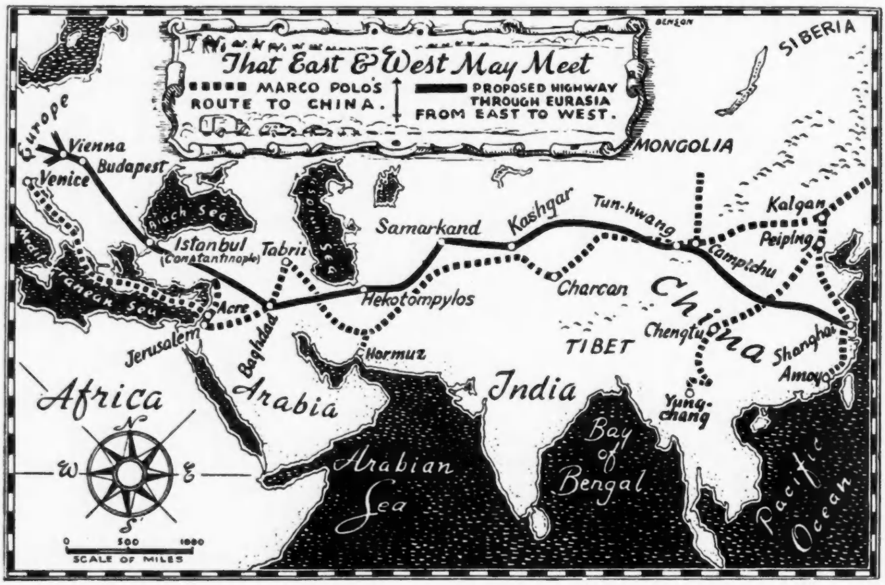
The power which, night and day, winter and summer, down through the centuries magically produced this life and hustling stream of people, was silk, the noble Chinese silk, enthroned on the camels' backs far above the throngs of humanity and the whirling dust on the roads; the silk in the lustrous folds of which the patrician ladies displayed their beauty, and the slaves executed their sensual dances in imperial Rome.

Chinese merchants and caravan leaders, of course, handled the silk commerce only as far as the western borders of the Middle Kingdom, at which junction the bales were taken over by men of other nations. Then through the whole of Asia, through Samarkand and Persia to Seleucia, through the Syrian Desert to Aleppo and Damascus, through Palestine to the coasts of the Mediterranean, went the precious commodity. From here Phoenician captains from Tyre, Sidon, and other ports brought the bales on galleys and sailing vessels to the big cities of the West, especially to Rome.

Thus more than 2000 years ago, silk was a communication link between many peoples and a connecting link between the Pacific and the Mediterranean.

The tale of the Silk Road has been revived in no small degree in our time by the discovery I was so fortunate as to make in 1900. While crossing the Lop-Desert for

the first time, I found on March 28 the ruins of the old Chinese city of Lou-lan, capital of the former kingdom of the same name. Though the name Lou-lan is mentioned in old Chinese documents and thus was known to Chinese and other scholars versed in the Chinese Era, no one knew where this country was located. In one of the houses of Lou-lan I found 157 manuscripts written on wood and paper. Many mentioned the name Lou-lan, and about a dozen of them were dated. One letter mentioned 4326 bolts of silk for Lou-lan's inhabitants.



Lou-lan had been a station on the Silk Road. An important garrison was stationed there to defend the caravans and commerce against the barbarians living in the vicinity. In the city were found caravanserais, inns, market places, and commercial establishments, and through its portals the big silk caravans to the Occident made their way. Lou-lan experienced its last period of prosperity during the years A.D. 265–310.

The river Tarim at that time flowed almost straight toward the east into Lake Lop-nor. Lou-lan was located not far west of the northernmost end of the lake. About A.D. 330, the lower part of Tarim changed its course and flowed south-east and south, forming in the southernmost part of the Lop-Desert a new lake, which was discovered in 1876 by the Russian N. M. Prjevalsky. The former course of Tarim and Lake Lop-nor had dried up. When I traced and partly located the lake, both had been dry for 1600 years. This interesting region was visited in 1906 by the

well-known American Ellsworth Huntington, and later by Sir Aurel Stein and the Japanese Tachibana.

In 1930, I sent Dr Nils Hörner and Parker C. Chen, two members of the expedition I then led, to Lou-lan. They traced and discovered Lake Lop-nor, which had reappeared in 1921. The water also returned to the old river bed and, in 1934, Mr Chen and I travelled in canoes down this river to its outflow in Lop-nor.

Now we can trace the Silk Road. Two thousand years ago, it went from Tunhwang straight across the Gobi Desert to the northern shore of Lop-nor, "The Wandering Lake", in its old location, continued over Lou-lan, and followed the shores of the lowest course of Tarim (Kum-darya). When the river and lake were diverted southward, Lou-lan became engulfed by the desert, deserted by its inhabitants, and forgotten. Thus, over a long period of time, the course of the Silk Road was interrupted, and the silk caravans sought other roads in the North via Turfan and in the South via Charkhlik.

But when, in 1921, the water returned to its old bed, the geographical location reverted to the one of the ancient era. In August, 1933, I suggested that the old imperial road of the Chinese silk—the longest, oldest, and best known, as well as most picturesque, of all roads on earth—be revived throughout Asia. It would spring back into existence again, not, as in olden times, to serve as a thoroughfare for silk commerce, but, aided by all modern and especially American technical resources, would become the chief artery for automobile traffic. In the Fall of that year a preliminary investigating expedition, which I headed, set forth. Several Chinese engineers and a number of Swedish scientists and mechanics took part in this expedition, and Edsel Ford contributed a truck to our motor fleet.

This road follows faithfully the course of the old Silk Road from Sian via Lanchow, Liangchow, Kanchow, Suchow, Ansi, Tunhwang, past Lou-lan's ruins, Korla, and Kutcha to Kashgar. Then, after crossing the 4000-metre-high pass

Expedition in the desert near Pei-shan.

Camels still in use on the Silk Road.

Terekdavan, it continues to Ferghana and Samarkand, to Iran and Baghdad, the Syrian Desert, Aleppo, and through Asia Minor to Angora (Ankara) and Istanbul (Constantinople), where it connects with the whole network of European automobile roads to Bremen, Boulogne, and other cities on the Atlantic Coast.

A gigantic undertaking it would be to construct such a road, but the building of the Great Wall of China was a greater one. Only within China need this automobile road be reconstructed, for although improvements are necessary within Russian Asia, from the eastern border of Iran to the Atlantic the roads are completed.

The Westerner who likes to take long automobile trips would surely get his fill on this road. The distance from Shanghai to the Atlantic in a straight line is 6600 miles; the road, with its curves, is about 9000 miles.

It would give the traveller the most interesting and wonderful motor trip on earth. Every day he would meet new and picturesque scenes of humming life in the cities of China, of the magnificent desolation of the Gobi Desert, of the Mongolian nomads with their herds of camels and horses, the sand dunes, the ruins of old cities, the new Lake Lop-nor, the new river Kum-darya, the oases of East Turkestan, Tamerlane, Samarkand, and the whole splendour of the Persian architectural creations, praised by poets.

A motor highway from Shanghai to Bremen or to Boulogne would become a new link of communication, a new means of co-operation, of understanding, and of peace between two continents, Asia and Europe; between two races, the yellow and the white; between two religions, Buddhism and Christianity; between two oceans, the Pacific and the Atlantic; and between two worlds, the Orient and the Occident.

Ever since the day when, thirty-seven years ago, astride my excellent camel I made my entry into old Lou-lan, I have been dreaming of these regions and of the possibility of making them beneficial to humanity. Nothing could bring me more happiness than to experience the realization of that dream.

Radio Exploration of the Upper Atmosphere

By J. A. Ratcliffe

(Mr Ratcliffe is a Lecturer in Physics at the Cavendish Laboratory, and is well known for his researches on wireless and the upper atmosphere.)

In 1902, just after Marconi's first transmission of wireless signals to America, it was pointed out independently by Kennelly in America and by Heaviside in this country that all theories would indicate that it should be quite impossible for the waves to travel round the "hump" formed by the earth in between unless there were a reflecting layer in the upper atmosphere. Because of the inadequacies of wireless technique it was not possible at that time to demonstrate the existence of this hypothetical layer, and it was not until 1924 that apparatus had developed to a stage where the first experimental test of the hypothesis was possible. The experiment consisted in sending Morse dots of a very short duration from a special experimental transmitter and receiving them at a nearby receiving station. It was found that for each single dot transmitted a succession of dots was received. The nature of the received signal can be seen by reference to Fig. 1, in which the trace was made by a spot of light moving from left to right across the paper, travelling at such a speed that it traversed the distance shown in one-thousandth of a second. The spot was caused to move in a vertical direction whenever a signal was received. For each dot transmitted a pattern similar to that shown was produced at the receiver. The peak marked G was due to the signal which had travelled straight over the ground, and the peak F_1 was produced by a signal which had been reflected from the upper atmosphere. The following peaks, marked F_2, F_3, etc., represented waves which had been reflected a second and third time from the upper atmosphere after intermediate reflections from the surface of the earth. By measuring the distance between G and F_1 it was possible to find the time taken by the signal in travelling to its reflection point and back again to the surface of the earth, and since it is known that wireless waves travel a distance of 300 kilometres (or 186 miles)* in a thousandth of a second it was then easy to calculate the height of the reflecting layer. The signal recorded in Fig. 1 had been a distance of 300 km. and back again, since it had taken $\frac{2}{1000}$ of a second in its journey, so that it was evidence for the existence of a reflecting layer in the atmosphere at this height.

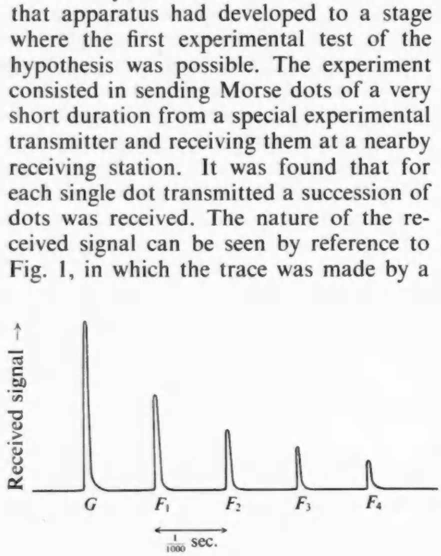


Fig. 1. Record produced at receiver by spot of light moving across paper from left to right, and caused to move upward by the received signal.

In order to appreciate the importance of this experimental result we must now give some account of our knowledge of the upper atmosphere as revealed by other experimental methods. It is known that the pressure of the air at ground level is equivalent to a barometric height of 76 cm.

* One kilometre is about $\frac{5}{8}$ of a mile.

of mercury, and experiment and calculation show that this air pressure falls off in the manner shown in Fig. 2. At a height of

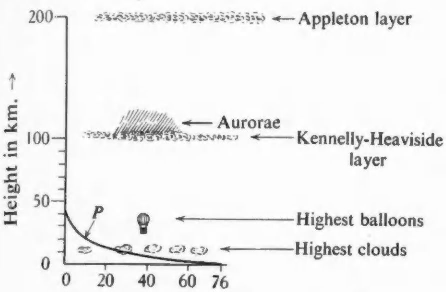


Fig. 2. The curve *P* indicates the upwards decrease of atmospheric pressure.

about 30 km. the air pressure is reduced to about 1 cm. of mercury, while at a height of 100 km. the pressure should be as low as that in a glow discharge tube such as is usual in a "neon sign". Balloons sent up to measure the pressure have been able to ascend to a height of just over 30 km., but no higher, since, as is obvious from Fig. 2, there is very little air even at that level to support them. It is at once clear that by using wireless signals reflected from the greater heights it is possible to obtain useful information about a region of the atmosphere which is completely inaccessible to direct measurement. As soon as this was realized scientists in various parts of the world started to devise wireless experiments to explore the upper atmosphere. It is with these experiments that we are concerned in the present article.

The records obtained were not always so simple as that shown in Fig. 1, but sometimes indicated that the waves had been reflected from two or more separate layers. Detailed experiments showed that it was always possible to divide the structure up into two main reflecting regions; one at a height of about 100 km. and the other at a height of about 200–250 km. The lower has been named the Kennelly-Heaviside layer, and the upper the Appleton layer, after Prof. Appleton, who was the first to demonstrate experimentally the existence of the layers, and who has added very considerably to our detailed knowledge of them.

The existence of reflecting layers in the upper atmosphere can be explained in the following way. The atmosphere is subjected during the day to very intense radiation from the sun which, because of its high temperature, sends out not only light but also X-rays and ultra-violet rays. We have already seen that the pressure of the upper atmosphere is extremely low, and the result of irradiating a low-pressure gas by X-rays or ultra-violet light is to electrify it, or, as a physicist would say, ionize it, so that the molecules of the gas are split into two charged particles known as ions. We must, therefore, picture the upper atmosphere as containing a large number of charged ions during the hours of daylight.

Now when a wireless wave encounters these ions it sets them oscillating, and each oscillating charge, acting just like a small wireless aerial, radiates a little wave of its own. If there are enough oscillating charges the waves which they radiate combine to produce a reflected wave. If this mechanism is worked out in detail it is found that, in order to reflect a wave of a given wave-length, a certain number of charged ions are required in each cubic centimetre of the gas, and if the wave-length is shorter the ions must be more numerous to reflect it. The relation between the number of ions and the shortest wave-length which is just reflected is calculable. It is therefore possible to determine the number of charged ions in unit volume of the upper atmosphere by sending up waves of different wave-lengths and finding the one which is only just reflected. If the wave-length of the transmitted dots is gradually decreased the reflecting layers at different heights cease to be effective in turn, and by knowing the critical wave-length corresponding to a given layer it is possible to deduce the concentration of the ions in

that layer. It has thus been possible to determine the maximum amount of ionization in each of the layers and to find how it varies with time both through the day and through the year.

The fact that the ionization should occur in the form of a layer can be seen as follows. When the sun's radiation is still a long way from the earth, it finds so very few air molecules that even if it ionized every one there would not be very many ions. As the radiation penetrates deeper and deeper towards the earth the number of air molecules becomes greater and greater, so that the number of ions increases. The process cannot go on indefinitely, however, because in the end all the useful radiation will have been absorbed and after that point is reached the amount of ionization must begin to decrease. It is therefore clear that at some level there must be a maximum of ionization.

The problem of determining theoretically the exact distribution of the ionization which would be produced has been solved by Prof. Chapman, and he has shown how we should expect the maximum ionization density to vary with the steepness of the sun's rays. He has shown that the ionization should become densest at midday when the sun is most nearly overhead and should decrease at sunrise and sunset, when the rays are more oblique, and he has also shown how the amount of ionization should vary throughout the year. By determining the critical penetration wave-lengths in the manner previously described it has been possible to follow the variation of the maximum ionization density throughout the day and throughout the year so as to check Chapman's theory.

It is found that for the Kennelly-Heaviside layer the predictions of the theory agree with the observations, thus indicating that the ionization is, in fact, produced by the sun's radiation. In connexion with the Appleton layer there appear to be anomalies which are not yet understood, but much new information is expected as a result of experiments which are being carried out simultaneously in the Northern and Southern hemispheres.

The experiments which we have described so far lead only to a knowledge of the *maximum* ionization density in a layer. By a slight modification of technique it is possible, however, to deduce information about the ionization at other levels. If the height of reflection is measured for a series of different wave-lengths it is found that a curve of the type shown in Fig. 3 is ob-

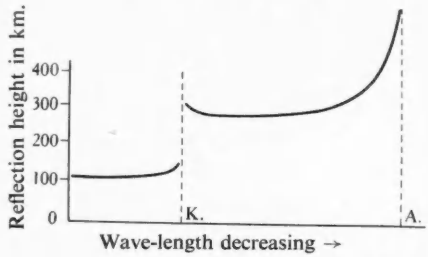


Fig. 3. This figure shows how the reflection height varies as the transmitted wave-length is varied. The wave-lengths marked *K* and *A* are the critical penetration wave-lengths for the Kennelly-Heaviside layer, and the Appleton layer respectively. For a summer midday *K* might be about 150 m. and *A* about 50 m.

tained, in which as the critical penetration wave-length is approached the height of reflection becomes gradually greater. A detailed analysis of curves of this type enables us to deduce values for the ionization density at different levels below the maximum. In this way it has been possible to show that the distribution of ionization in the atmosphere is somewhat as shown in Fig. 4, where the Kennelly-Heaviside region is shown as a thin layer and the Appleton region as a thicker layer with a greater maximum density.

The fact that the upper region is very much thicker than the lower is of very fundamental importance, for Chapman has shown that the thickness of an ionized region should depend on the temperature of the atmosphere at the level concerned, and also on the molecular weight of the gas which constitutes it. It can be shown

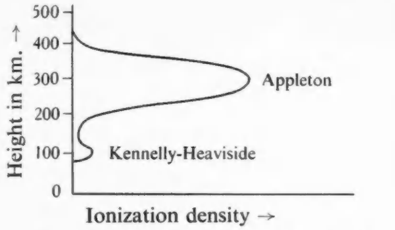


Fig. 4. Distribution of atmospheric ionization.

that the existence of the thick upper region represented in Fig. 4 requires either that the temperature should be about 1200° C. or that the gas should be almost entirely in helium. It is not at present known which of these two possibilities is the correct explanation.

Our account so far has been concerned with what may be called the normal behaviour of the upper atmosphere. The variations with the day and with the season appear to follow the course which would be indicated by a simple theory. We must now give some account of abnormalities which have been observed to interrupt this normal course on special occasions.

As an introduction to a case of a very marked abnormality we show in Fig. 5 the behaviour observed on a normal winter's night when a wave-length of 75 m. was used. The absence of reflection near the middle of the night is interpreted as being due to the fact that the charged ions produced during the previous day had combined together again to make neutral molecules. A few days later the results shown in Fig. 6 were obtained. The reflections from the Appleton layer behaved much as in the previous case, but between about 3.30 and 5.30 there was a marked reflection (accompanied by multiple reflections) from the Kennelly-Heaviside layer. Now the remarkable thing about this reflection is that it represents an increase of ionization at a height of about 100 km. right in the middle of the night, at a time when X-rays or ultra-violet light from the sun could not be incident on the atmosphere.

Abnormalities have also been observed for many years in connexion with terrestrial

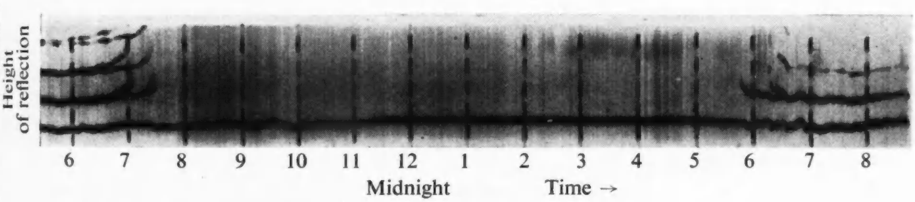


Fig. 5. A record of the height of reflection of a 75 m. wave made by an automatic apparatus. The reflection is from the Appleton region except between 8 p.m. and 6.30 a.m. when no reflection occurs.

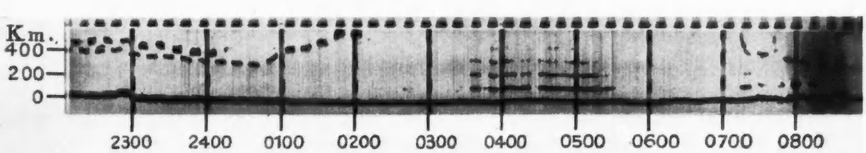


Fig. 6. In this automatic record the signal reflected from the Appleton layer is represented by an interrupted trace. This is due to a special arrangement at the receiver and has no significance in the present connexion.

magnetism. On some occasions the ordinary smooth diurnal variations are replaced by very abrupt abnormal variations known as magnetic storms. These storms may occur in the middle of the night, and it is supposed that they represent a sudden increase of the upper atmosphere ionization very similar to that postulated to explain Fig. 6. Experiment has shown that there is a close connexion between magnetic storms and abnormal ionization revealed by wireless experiments.

A suggestion has been made that the ionizing agent responsible for these abnormal effects is a stream of charged particles emitted from the sun, and it has been pointed out that such a stream would be deviated by the earth's steady magnetic field, since it would behave like a current of electricity. Detailed calculations have demonstrated that under certain conditions the charged particles would impinge on the dark side of the earth. If this were so it would account for the occurrence of abnormal ionization in the night time.

We also have in this theory an explanation of the aurora, since it is known that a stream of charged particles incident on a low-pressure gas produces a brilliantly coloured discharge. The theory of the deviation of the earth's particles by the magnetic field explains why the aurora is most commonly seen at a distance of about 22 degrees from the North and South Poles. On the occasion of the very intense aurora which was seen in this country in January 1938, it was observed that an intense magnetic storm was taking place and that the propagation of all wireless waves was very severely disturbed.

There appears to be some correlation, at present not fully understood, between the occurrence of streams of charged particles from the sun and the occurrence of spots on the surface of the sun. It is known that the spottedness of the sun's surface shows a periodicity of about 11 years, and the frequency of magnetic storms follows this sunspot cycle closely. Although detailed wireless investigations of the upper atmosphere have only been made during the last 6 years, there is already enough evidence to show that the ionization of the upper atmosphere follows the 11-year cycle in some respects. This fact is so well established that in planning commercial wireless services for great distances it is necessary to make allowance for the fact that the most suitable wavelength will be expected to change from sunspot maximum to sunspot minimum.

From the foregoing account it will be clear that the normal diurnal and seasonal variations of the upper atmospheric ionization are now comparatively well understood, at any rate so far as the Kennelly-Heaviside layer is concerned. There appear, however, to be abnormalities in connexion with the Appleton layer. The evidence seems to show that there is a change in the character of the atmosphere at heights above 100 km., which may be due either to a higher temperature, or to the presence of helium gas. As regards the finer details of the abnormalities which are observed both by night and by day, very little is at present known.

This is a satisfactory state in which to leave an account of any scientific subject. It will be clear that part of the problem can be considered to be settled but that a very important part is still, in more than one sense, in the air. It is to be hoped that the intensive investigations which are at present being carried out all over the world will rapidly lead to a solution of the next series of problems.

How Hot are the Stars?

By R. v. d. R. Woolley

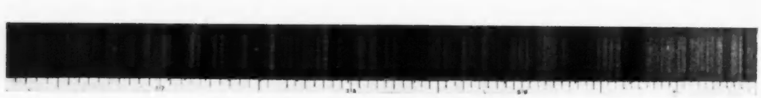
(Dr Woolley wrote last month on the meteor that just missed the earth. In this article he describes how astronomers can announce with confidence the temperature of the outside of a star.)

ALTHOUGH the nearest star, our own sun, is ninety million miles away from us, and all the other stars are very much further away, we are able to find out a great deal about conditions on the surfaces of the stars. We can describe the temperatures of the stellar atmospheres with a fair degree of precision and confidence. Since we have no means of sending any sort of thermometer to any star, we must rely for our information on something which the star sends to us, and the only something available is starlight.

The Fraunhofer Lines

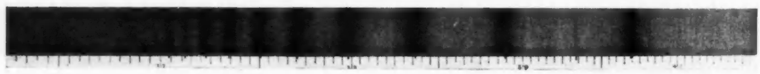
The first attempts at analysing the most abundant starlight, that is to say sunlight, consisted in passing a beam of light through a prism, which breaks up the light into the colours of the rainbow—red, orange, yellow, green, blue and violet. Newton passed sunlight through a circular hole in the shutter of his window and broke it up into its constituent colours with a prism. Had he used a fine straight slit instead of a circular hole he might have seen what was first observed by Wollaston early in the nineteenth century, that the band of colour from red to violet, or spectrum as it is called, is crossed by a number of dark lines. These lines are usually called the Fraunhofer lines, although Fraunhofer saw them after Wollaston. It was at first thought that these lines were natural divisions between the pure colours, but they are more interesting than that. Their significance was found by comparing the solar spectrum with the spectra emitted by luminous things in the laboratory—flames and furnaces in the early days, and later electric arcs and sparks. If you dip a wire wound round with asbestos into a solution of common salt in water, and thrust the wire into a Bunsen flame, an intense yellow flame appears. If you examine the light from such a flame by passing it through a narrow slit and then dispersing it with a prism, you find that the yellow light is not drawn out into a continuous spectrum of colour from red to blue but consists of two bright yellow lines close together. These lines are conspicuous in any flame into which any sodium salt has been introduced, and are in fact the strongest spectral characteristic of the sodium atom. Now among the most conspicuous of the Fraunhofer lines are two dark lines close together in the yellow region of the solar spectrum. If you measure carefully the angles through which these two Fraunhofer lines are refracted by a particular prism, you find that these angles are exactly the same as the angles through which the two bright lines in the sodium spectrum are refracted by the same prism: from which it was quickly and correctly deduced that these two Fraunhofer lines are formed by sodium atoms in the solar atmosphere.

It is a very wide principle in physics that if a system emits a particular vibration readily it will absorb the same vibration: this principle goes by the name of resonance and has applications to sound waves and to tuning radio sets. We think of light as a wave phenomenon, and of light waves as very short wave electromagnetic waves like radio waves; this



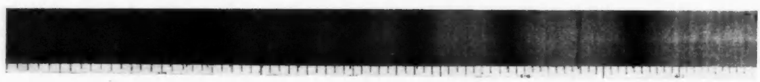
W. Huggins

Spectrum of the sun.



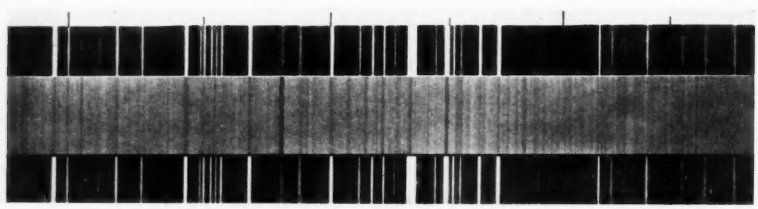
W. Huggins

Spectrum of Vega.



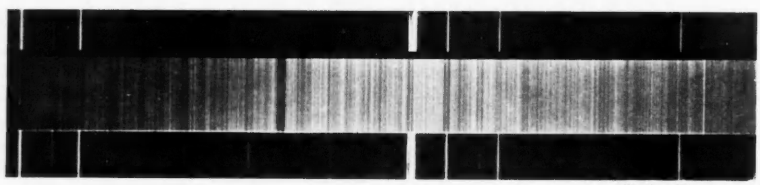
W. Huggins

Spectrum of Sirius.



Yerkes Observatory

Spectrum of ζ Ursae Majoris. The *central* band shows the spectrum of the star; the upper and lower bands are laboratory spectra added for comparison.



Yerkes Observatory

Spectrum of the above star at a later date. Each line in the spectrum is doubled, showing that the star is a binary system.

From Sir J. Jeans' *Through Space and Time*.

helps us to understand the principle of tuning by which the sodium atom acts like a tiny emitting set sending out its particular wave-lengths when it is heated in a flame in the laboratory—and like a receiving set when it is in the sun. The absorption can actually be demonstrated in the laboratory by passing light from a white hot source —a very bright incandescent filament— through a sodium flame. The spectrum of this combination is a continuous spectrum with dark sodium lines on a bright background.

How Hot are the Stars?

There are thousands of Fraunhofer lines in the solar spectrum, and most of them have been found to have the same wave-lengths as bright lines in the spectra of various terrestrial elements. The calcium lines are the strongest and the iron lines are the most numerous. We may seem to have wandered from the subject of stellar temperatures, but it is the lines in the spectra of the stars which provide one method of determining these temperatures. This is because the combination of lines which you get in the spectrum of a terrestrial element depends on the way in which you treat it. We have three main ways of exciting an element in the laboratory to make it send out its spectrum. The gentlest method of treating it is to heat it in a flame or in a furnace, the middle method is to introduce some of the element into an electric arc, and the violent method is to introduce it into an electric spark. Some lines are very strong flame lines, and some lines are very strong spark lines, while arc spectra contain both flame and spark lines. Now it is found that some stars such as Betelgeuse show the flame lines very strongly, while others such as Canopus and Procyon show the spark lines. The sun is intermediate between the two. It is at once clear that the surfaces of Canopus and Procyon are hotter than that of the sun, which is in its turn hotter than that of Betelgeuse. This analysis of starlight has been organised into a systematic way of inferring the temperature of a stellar atmosphere by estimating the relative strengths of the various lines shown in the spectrum.

There is another way in which an analysis of starlight may be made to give the temperature of the stellar surface. This can be illustrated by thinking of the radiation from a solid body which is being heated up in the dark. At first we see nothing, though we may feel heat radiated from the body if we stretch our hands towards it; but as the body gets heated it glows with a dull cherry red. If we examine the spectrum of a red hot object, we find that only the red end of the spectrum appears. As it gets hotter the yellow comes up, and as it gets hotter still green and then blue will appear. The red hot object shows no yellow, a candle flame shows red, yellow and a little green, while an electric light filament shows red, yellow, green and a little blue. That the sun shows strong green, blue and even violet is evident that it is much hotter than the electric filament.

The Trick Problems

But we must be careful. There are some luminous bodies which do not fit into this scheme at all—for example, neon signs. A blue neon sign is not necessarily hotter than a red one. When one starts investigating trick problems such as the temperature of a neon sign, one must ask oneself what one means by temperature. Give a careful scientist a thermometer, a hot cup of tea into which you have just put some cold milk, and ask him what is the temperature. Note his action. He *stirs* it. It is only when a cup of tea is properly stirred that it has a temperature in the common or garden sense at all. It is only when a body is homogeneous as regards heat—when, in other words, it is in thermodynamical equilibrium—that it has an unambiguous temperature.

What about the stellar surfaces? Are the atmospheres well stirred, are they sufficiently close to thermodynamical equilibrium to have well-defined temperatures?

The answer is yes and no. However you define it and however you measure it, the solar temperature is always between 5740 and 7000° C., but this fairly wide range of temperature indicates a departure from heat equilibrium. All the same, even if the study of stellar spectra does not lead to a simple temperature for each stellar surface, it gives us great insight into the physical state of each surface.

TEMPERATURES FROM THE COLOURS OF THE STARS

β Orionis	16,000° C.
α Lyrae	14,000
Procyon	8,000
Capella	5,800
Aldebaran	3,000
Betelgeuse	2,600
β Pegasi	2,850
α Herculis	2,500

The Riddle of Sirius

By L. Infeld

(Dr Infeld's latest article—about the "white dwarf" companion of Sirius—is closely connected with Dr Woolley's. To get most value from the two articles, Dr Woolley's should be read first.)

THIS is a story covering eighty years of research! The mystery surrounding Sirius, revealed by astronomical observation, was cleared up only by investigations carried out with the aid of modern physical theories. Let us now give a short account of this drama, which could well be called "The Sirius Case".

Sirius is the brightest star in the heavens. It is fairly near our earth, being only about nine light years distant. Light, then, travels about nine years from Sirius to our eyes. Compared with the vast spaces which the telescope on Mount Wilson enables us to penetrate, Sirius lies in that part of the universe closest to us. In the sun's position Sirius would appear to us nearly thirty times brighter than the sun, and its intense radiation would immediately destroy all life on our earth. In the course of our tale we shall meet the other acts in this drama.

Act I takes place in 1844. In that year Bessel discovers an interesting fact. Sirius moves! Just as the earth and other planets turn around the sun, so Sirius turns around some body undetected by us. One complete revolution takes about fifty years. Thus we conclude that some invisible star must be attracting Sirius. This leads us to:

Act II. In 1862 Clark discovers that Sirius has a faint companion whom we shall call Sirius B. Sirius and this companion belong to the type of star known as *double stars.* Together they turn about a common point called their *centre of gravity*. From observation of their motion we can deduce their mass. The mass of Sirius is about twice that of our sun, and the mass of its companion somewhat less than that of our sun. In other words, the mass of Sirius is three times greater than that of its companion. A new problem arises. Why is the light of Sirius so much stronger than that of its companion? Sirius is the brightest star, and yet the powerful telescopes of the second half of the nineteenth century were essential for the discovery of its companion, of a mass only three times smaller. The answer seems simple enough. Sirius has a high temperature, its companion has already cooled off and has, therefore, a much lower temperature. A sheet of white hot iron shines much more brightly than a sheet of red hot iron. Thus also Sirius sends forth much stronger radiation than its companion. But this answer is incorrect and leads to false conclusions.

Act III. In 1914 Adams studies the radiation emitted by Sirius B. He discovers a

strange fact. Sirius and its companion have the same type of spectrum. Continuing with our comparison of the two sheets of iron we could say: it is as though both were white hot rather than one white hot and the other red hot. A difficulty is evident here. How is it that Sirius is so clearly visible, whereas its companion can be seen only through powerful telescopes? There seems only one possible answer: Sirius must be larger than its companion. Imagine a large and a small sheet of iron placed at equal distances from us and both heated to the same temperature. Due to its size, the large one will appear to us much brighter than the small one, although every inch of the two surfaces radiates in exactly the same way. We now answer the question: how big, or rather how small, is Sirius B? Sirius B is approximately the same size as our earth or, more accurately, somewhere between the size of the earth and that of another planet in our planetary system, Uranus. But although this star resembles the earth in size its mass is 250,000 times larger.

We are approaching the climax of our story. If Sirius B is so small and its mass so great, then we must necessarily conclude that its average density is incredibly great. The average density of one cubic centimetre of Sirius B is approximately 100 lb., that is, 5000 times greater than that of lead. The mass of one cherry from Sirius B would be about 100 lb. A matchboxful of matter from this star would have a mass of about one ton! These strange and paradoxical conclusions need independent confirmation. It is here that modern physics takes its part, supporting the conclusions which have been drawn and leading us to:

Act IV. The idea of matter having

tremendous density is not inconsistent with the conclusions of modern physics, although it seems strange to us with our everyday experiences. Physics has taught us that matter in the entire universe is composed of only a few kinds of elementary particles. There are the very light electrons and the two thousand times heavier protons and neutrons. These constitute the atoms of all known elements. The dimensions of these elementary particles are very small compared with the atomic dimensions. It is, however, possible that in some cases space is filled with these elementary particles much more closely packed than in the atoms of the commonly known elements. Under the strange conditions created by incredibly high temperatures inside the small heavy stars, some space may be filled with an incomparably greater amount of matter than under normal conditions and the result may well be tremendous average density. Our conclusions concerning these enormous densities seem so hard to believe that it would be a relief to find them supported by an independent argument gained in a different way. Just such an argument is supplied by the general theory of relativity, which appears in the last act of our drama:

Act V. To understand the final stages of the investigation we must mention one result of the general theory of relativity.

At a high temperature gases emit light. This light may be decomposed by a prism or, more efficiently, by what is known as a spectroscope. A spectroscope analyses light, splits it into its component parts, into its *spectral lines*. These spectral lines tell us something about the structure of the atoms from which the light was emitted. They are the "fingerprints" of the elements; certain well-defined spectral lines belonging to each element. Let us imagine the spectral lines of some element, say, hydrogen, firstly sent out from the sun and then again produced on our earth. The arrangement of the spectral lines, characterizing the chosen element, will be the same in both cases. But the lines emitted by the element on the sun will be slightly shifted if compared with the lines of the same element on our earth. This effect, predicted by the general theory of relativity, will only be very faint. The strong gravitational field of the sun is responsible for this difference in the spectral lines. Has experiment confirmed this conclusion of the general theory of relativity? The effect as foreseen by the theory is very small indeed. It lies in the neighbourhood of experimental error. Experiment seems to confirm the theoretical prediction, although its verdict is not very clear owing to great technical difficulties. At this point a new idea may be put forward. The gravitational field of the sun gives a certain effect, shifting the spectral lines. This effect is weak but it would be much stronger if the gravitational field of the radiating star were stronger. But the gravitational field of Sirius B is very strong. Observing the light emitted from an element on the surface of Sirius B, through a spectroscope we should notice a distinct shifting of the lines as compared with light emitted by the same element on our earth or even on the sun. The theory permits not only qualitative but also quantitative predictions. These were fully confirmed by Adams in 1925. If we believed in the theory of relativity and doubted only the existence of stars with such enormous density we could say: Adams' result confirms the great density of Sirius B. If, however, we still seek some experimental confirmation for the general theory of relativity, we could regard Adams' result as evidence in its favour. This experiment closes the Sirius case for the time being.

The solution of the Sirius case actually marked the beginning of new researches. Sirius B is only one of very many known members of the family of "white dwarfs". Some of them are of even greater density. Many problems are connected with the constitution of these white dwarfs, and what we have described here forms only a small part of a much broader and more general investigation which is still by no means at an end.

Reviews

A Continent of Contrasts

THERE is a peculiar anthropomorphic quality about the fauna of Australia that makes it as interesting to the non-expert as it is odd zoologically. The tree bears which take a delight in playing leap-frog in the drawing room of a house while the master is away, the kangaroos which will race a car across the plain for miles, and the lyre birds, with their human sense of fun—these seem much nearer to man than the stoats, foxes and rooks of our own countryside.

Mr Francis Ratcliffe,* whose book betrays a delightfully human approach to animal problems, was sent out to Australia to discover how far the depredations of flying foxes on the fruit crop could be reduced. Briefly, he found that these animals existed in such large numbers, and "camped" in such inaccessible mangrove swamps, that control would be impossible. On his journeyings, however, mostly in Queensland and South Australia, he met many strange things. He encountered what he took to be a lyre bird imitating a cat bird, a jackal, and a dog; it turned out to be a cat bird imitating a lyre bird imitating those things. Once he had the luck to hear a lyre bird imitating a stock-whip bird. It started with a poor attempt. "Then an obviously dissatisfied silence. Then he tried again. This time it was better. Again a thoughtful silence and a new attempt. Now he had succeeded in capturing some of the mechanical venom which marks the stock-whip's crack. He repeated the attempt some dozen times...at last he was satisfied, the miracle had been achieved. He signified

Camp of flying foxes.

* *Flying Fox and Drifting Sand*, by Francis Ratcliffe (Chatto and Windus, 16*s*.).

his pleasure by letting rip the lyre bird larrikin whistle as loudly as his well-trained lungs would blow it. I somehow felt disappointed at the absence of applause from the forest shadows. I know I instinctively raised my hands to clap."

One thing especially puzzled Mr Ratcliffe. Why did not the foxes (browny-red animals with a reputation for lamb-killing) exterminate the rabbits in time of drought? He was in the inland region at a time when the rabbit population had been decimated by drought, and saw as many foxes as rabbits. But although rabbits are the fox's natural prey, and fall victims in huge numbers when a rabbit plague is on, the foxes studiously refuse to kill off the few drought-surviving rabbits and thus rid Australia of a national menace far more potent than that of fruit bats or soil erosion.

The problem of soil erosion was the reason for Mr Ratcliffe's second visit to Australia, and a very horrible picture his report presents; a picture of farms overstocked at 25 sheep to the square mile; of paddocks with the bush completely stripped, which might not recover; of thousands of sheep drowned in sudden floods; and of the famous Birdsville track innocent of traffic and with its stock-drivers idle. He found that the mulga bush is not reproducing itself at all, as a rabbit plague invariably occurs before the young shoots have time to grow stout enough to resist; when the old mulga dies there will be so many more thousands of square miles of desert.

And yet, Mr Ratcliffe found the Australians a kindly cheerful race. His book, on the whole, is in a cheerful vein, though he does not minimize the desperateness of the situation. It is amusingly written, and covers a wide variety of subjects, from the psychology of the "half-hat" stockman to the practical points of lumbering. The many illustrations are of the first class.

"We counted eighty-four dead cattle on the margin of a small depression which had once contained water", wrote R. H. Croll, whose book* also deals with the semi-deserts of South Australia. In one place, some joker had leaned a horse, mummified by the dry atmosphere, against a tree. Mr Croll was seeing the land after five years of drought, and pushed his camel down the dry bed of the Finke, which inscrutable river he would later see in flood. One day he camped on a dry plain, and returning in fourteen days after a shower of rain found a tall plant in full bloom where the fire had been. That is the significant thing about Australian deserts. Gazing at a huge dried "clay-pan" stretching to the horizon, one finds it impossible to believe life has not entirely vanished. Yet if rain should fill out the hollow again, life will revive at once. The water-holding frog, for instance, fills itself with water when the pool begins to dry, and burrows deep. The mud closes around it, and there it sleeps for the period of the drought, unless a black should smell it out and dig it up for the sake of the water it contains, which remains fresh and sweet.

In a continent which can provide such strong contrasts, between rushing torrents and dry beds, between the tropical vegetation of Palm Valley and the Martian landscape of the Coober Pedy opal workings, there is always hope. Mr Croll and Mr Ratcliffe both found many settlers living on hope, with eyes permanently strained watching for the rain clouds. But a cycle of better seasons will come, and with it prosperity for the long-suffering inhabitants of the devastated areas which both authors portray.

F. W. KIDNER

British Birds

The Practical Handbook of British Birds went out of print in 1934. The authors state that this handbook† is far more than a new edition of that book; it has been remodelled, contains much new matter and has coloured illustrations of birds in different plumages.

* *Wide Horizons*, by R. H. Croll (Angus and Robertson, 9*s* 6*d*.).

† *The Handbook of British Birds*, by H. F. Witherby, Rev. F. C. R. Jourdain, N. F. Ticehurst, and B. W. Tucker. Vol. I, H. F. and G. Witherby, 21*s*.

In the Introductory Notes the authors explain the lines upon which they have worked. The notes on each species are divided into sections, viz. habitat, field characters and general habits, voice, display and posturings, breeding, food, distribution, migrations, characters, and allied forms; there is also a detailed description of plumages.

Under "voice", the song and principal notes of the various species are elaborately recorded. The difficulties of this subject are admitted; a particular sound rarely conveys the same impression to different individuals, and a trained musical ear obviously records gradations in tone and pitch unappreciated by the unmusical. The sound-system employed is clearly explained by the authors, and the sometimes diverse renderings of songs and notes as heard by two or more listeners are included. Considerations of space and expense have forbidden the employment of the methods of song recording evolved, e.g. by Prof. W. Rowan, but their use is rightly commended to observers. Within these limits everything possible has been done to make bird sounds comprehensible both to experts and to the uninitiated.

The sections on Display and Posturing are most valuable; to students of bird psychology they will often prove the most attractive parts of the book. As the authors admit, they show the many gaps in our present knowledge of the "courtship" of even our commonest species, and will therefore stimulate further examination of many fascinating problems.

The Song Chart, prepared by Mr H. G. Alexander, is based upon observations made chiefly in the south of England and the Midlands; it represents the normal song duration, and thus, on the whole, gives an accurate survey of the songs of the species mentioned. Local observers will discover variations. In West Somerset, for instance, the woodlark occasionally sings in late August and early September, and frequently in December and January if the season is mild.

The coloured illustrations show accurately the different stages of plumage which are often so confusing even to the expert. They must not, of course, be compared with pictures whose aim is aesthetic rather than scientific. To beginners these plates will probably prove even more useful than the textual descriptions.

A good many rare species are described which have appeared once only in England or Scotland. British ornithologists are agreed that such birds, if they have reached here unaided, should be included on the British list. But whether a single occurrence here of a vagrant whose geographical range is remote justifies it being called a "British bird" is a question upon which there is considerable difference of opinion.

Acknowledgements are made to numerous helpers. Field observers who have studied certain species intensively, while agreeing generally with the authors' conclusions, will be more critical on points of detail. For instance, social gatherings of ravens take place in spring and late summer, not only in autumn and winter; the turn on to the back is performed by both sexes, not by the male alone, and has been observed in every month of the year, as well as in the breeding season. The "wheet" note of the chaffinch in spring is uttered by the female as well as the male. In the notes on the corn bunting further use might have been made of Col. and Mrs Rykes's exhaustive observations.

If the later volumes fulfil the promise of this one they will together form a comprehensive summary of modern knowledge of British birds which will be invaluable to all ornithologists.

These few criticisms will not affect the admiration which every lover and student of birds must feel for this monumental work. Specialists and amateurs have combined to make it a most complete survey of modern knowledge of British arifauna. There can be no doubt that the later volumes will fulfil the promise of the first, and that together they will prove invaluable to all ornithologists and field-naturalists for many years to come.

E. W. HENDY

The Speed of Fish

By Frank W. Lane

Considerable ingenuity has been displayed by ichthyologists and others in attempts to determine the very difficult problem of the speed at which different species of fish can swim. From the work which has been done, it is possible to indicate the types of speeds which can be expected from various fish, and in this article I shall mention some of the methods which have been employed and the results obtained.

One of the most thorough investigators of the whole question of fish locomotion is a French scientist—M. A. Mangan. These are some of the methods he has employed. Timing a fish passing between two fixed obstacles; noting the comparative speeds of fish and a ship on which he was travelling; noticing the time taken by a fish to pass the vessel on which he was travelling, and then calculating its speed from the known speed of the ship; taking cinematograph pictures of fish in motion and then working out their speeds from the distance travelled from one picture-frame to another in a given time.

The following translation from the French describes what is perhaps the most original of his methods. "In the case of species which it is not possible to observe in their natural habitat, I have harnessed specimens to a delicate speed indicator. The apparatus is similar to that constructed by me in 1912 in conjunction with M. F. Houssay to determine the speed of birds.

"It is composed of a pulley mounted on ball bearings on a horizontal axis. The frame bearing this pulley is itself made to move round a vertical axis supported on ball bearings. A thread of very fine but strong silk being wound round the pulley, its free end is attached to the fish and the whole apparatus adjusted to allow the fish to pull horizontally on the thread. Beside the large pulley there is another smaller wooden pulley on which is mounted a brake for the purpose of determining the amount of 'traction' exerted by the fish.

"The fish unwinds the thread from the large pulley, which revolves actuating a Deprez signal once every revolution, which determines the number of revolutions made and the distance traversed. The time is also checked carefully and a simple calculation gives the speed at which the fish has travelled."

* * * *

The full list of speeds which he obtained is contained in long and somewhat technical schedules in the *Annales des Sciences Naturelles*, Volumes XII and XIII. He divides fish into different categories according to their speed. As rapid fish he mentions dogfish, blue shark, sturgeon, salmon, pike and tunney.

By the use of cinematography he found that blue shark were capable of 11 m. per sec., or 24 m.p.h.; tunny, 6 m. per sec., or 14 m.p.h.; and salmon, 5 m. per sec., or 11 m.p.h. But, as will be seen later, these speeds must not be taken as representing the absolute maximum of which the fish are capable.

Before leaving M. Mangan's investigations it is interesting to note that he classes flying fish among the most rapid swimmers. In this he is fully in accord with other observers. Dr Hankin, for example, who has made a special study of the flight of these remarkable fish, says that under favourable conditions they may attain a speed of over 50 m.p.h.

These fish attain their speed by rushing along near the surface of the water with their caudal fins moving very rapidly from side to side. They then make a sudden jump out of the water and use their pectoral fins as "planes". They do not fly in the literal sense of the word but, possibly by making use of air-currents, they are able to progress as far as a quarter of a mile before again alighting on the water.

* * * *

Considering its popularity with anglers it is not surprising that more is known concerning the speed of the salmon than of any other fish. A compatriot of M. Mangan, Inspector Kreitmann, once carried out some tests on the River Vienne to determine the speeds of fresh-water fish, and during these "trials" a salmon clocked 8 m. per sec., or 18 m.p.h. A Belgian observer, who conducted experiments on salmon before Inspector Kreitmann, came to the conclusion that for short distances they could maintain a speed of 20 m.p.h.

It might be thought that fish must use up a tremendous amount of energy to reach speeds which are so much in excess of the best man is capable of, either in swimming or when aided by machine-power, as in the submarine. Actually, a man swimming at say 4 m.p.h. is using more energy, in proportion, to a shark which is travelling at 20 m.p.h.

This was conclusively proved in an interesting experiment which was carried out in the Princeton University swimming pool some years ago. A powerful swimmer, weighing 170 lb., was harnessed to a fishing line and an angler, using a swordfish rod, attempted to "land" him. The swimmer covered 50 ft. with a fast crawl and then the angler tightened the drags until he stopped him. The swimmer then changed to a powerful breast-stroke and put such a tremendous strain on the line that it nearly broke.

After 15 min. the struggle was a stalemate, the swimmer could make no further headway and the angler could not haul him in. The line was humming like a tuning-fork under an 80 lb. strain. Writing afterwards the angler said: "Throughout the tussle I had been comparing it with one against a big fish, and, though the man's speed was less and his surges not so violent as those of the fish, his power was amazing. I estimated that he forced me to use as much power as I would have used against a 300-pounder."

This was proved subsequently when tests were carried out with a shark. "In regular pull, the man registered about 0·3 of a lb. per lb. of weight, while the shark registered but 0·17 of a lb."

* * * *

One reason why fish can reach a high speed for a comparatively small expenditure of energy is due to a little-known perfection of their make-up which was not fully understood until a few years ago. It was found that quite small fish, when held with their heads immersed in water, squirted through their gills a jet of water which rose several feet in the air.

A realization of what these jets meant came about in the following manner. A device, which claimed to reduce greatly the obstacles to the passage of a ship through the water, was invented by an American engineer. The invention was called an "induced stream-line system", and its main feature was the ejection of streams of water through nozzles in such a way as to overcome friction and water resistance.

The significance of the jets of water emitted by fish was then appreciated. They have had an "induced stream-line system" since the dawn of history! It was found that of over 300 species of swift-travelling fish which were examined, over 90% possessed gill clefts at the correct place for the most efficient use of jets of exhaled water.

When, in addition to this adjunct to speed, it is remembered that the body of a swift-travelling fish is perfectly streamlined, its skin is so smooth that it offers practically no resistance to the water, and

that the beautifully moulded bullet-shaped head, with the pointed snout, is a perfect cut-water, it is not surprising that a fish can reach a speed beneath the water which compares not unfavourably with speeds reached by animals on land.

* * * *

It is worth noting here that it is almost impossible to measure the fastest speeds of which certain fish are capable. A Mako shark, for example, has been filmed during a leap in which it put nearly 30 ft. between itself and the water. What colossal speed must it have attained to hurl its 600 lb. body that distance out of the water!

The leaping powers of the tarpon are proverbial. They have been known to jump 18 ft. into the air and cover an arc of over 30 ft. during a vicious attempt to get rid of the angler's hook. Small wonder that the late Lord Northcliffe was advised, by an old American angler, to remember when he bought tarpon tackle "that you may expect to hook something like a thirty knot torpedo-boat".

Zane Grey, perhaps America's greatest big-game fisherman, once had an experience with a bonefish which, happily, gives us some indication of what one of these fish is capable when really hard pressed. He was angling in waders in shallow water when he hooked one of these miniature torpedoes. It darted away with such speed that he feared the line would break. To ease the strain he commenced to run in the same direction as the fish. He covered 50 ft. while the bonefish took 400 ft. of line. If we assume that he ran at only 5 m.p.h., that gives a speed for the bonefish of nearly 40 m.p.h.!

The following table, which has been compiled from various sources, is intended to give an approximate maximum speed for the fish named.

I have omitted the fastest fish in the world—the swordfish. It obtains its food by rushing among shoals of smaller fish and stunning or killing them with its sword.

NAME OF FISH	SPEED IN M.P.H.
Tench	7
Carp	7
Eel	$7\frac{1}{2}$
Roach	10
Barbel	11
Pike	15
Salmon	23
Trout	23
Blue Shark	30
Mako Shark	35
Tarpon	40
Tunny	40

A swordfish once struck a wooden ship with prodigious force. Its sword pierced through the copper sheathing, an inch of the undersheathing and then a 3 in. plank of hard wood. That was a good start, but the fish had only just started its journey of exploration.

Its sword next pierced through the 12 in. of white oak timber and a hard oak ceiling $2\frac{1}{2}$ in. thick. Finally, the sword entered an oil cask and broke off, thus forming a very convenient bung.

Altogether the fish had penetrated 20 in. of timber. Judging by the material of which the sword was composed it was obvious that by no ordinary means could it have been forced through copper sheathing and nearly 2 ft. of wood. The fact of clean penetration showed that the fish, at the moment of impact, must have been travelling at not less than 60 m.p.h.!

P.H.

ooden ship
rd pierced
an inch of
3 in. plank
start, but
journey of

the 12 in.
oak ceiling
entered an
ning a very

ated 20 in.
al of which
as obvious
ld it have
athing and
t of clean
sh, at the
een travel-